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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXV.—No. 2991.] *LONDON: FRIDAY, APRIL 27, 1923.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

Aveling & Porter, Ltd., ROCHESTER. 1108

Steam Road Rollers & Tractors.

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For Sale, at Low Prices. Three 60 inch Water-driven Hydro EXTRACTORS by Watson, Laidlaw & Co., Ltd.; new condition. JOHN H. RIDDEL, LTD., 40, St. Enoch Square, Glasgow.

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Tank Locomotives. Specification and Workmanship equal to Main Line Locomotives. R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1133

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Æ Tubes, Plates, Rods, &c., in Brass and Copper. ALLEN EVERITT & SONS, LTD., Kingston Metal Works, SMETHWICK, BIRMINGHAM. 1344

Plenty and Son, LIMITED, STATIONARY, STEAM AND MARINE ENGINEERS, NEWBURY, ENGLAND. 1211

Steam Hammers (with or without guides). Hand-worked or self-acting TOOLS for SHIPBUILDERS & BOILERMAKERS 1189 DAVIS & PRIMROSE, LIMITED, LEITH, EDINBURGH.

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Bever, Dorling & Co., Ltd., BRADFORD. HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896

Cranes.—Electric, Steam, HYDRAULIC and HAND, of all types and sizes. GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 1137

Telegrams:—"Cylinders," Birmingham. Weldless-Steel Tubes for Water-tube Boilers, Superheaters, Stoking, Hydraulic Work, Boring Rods, &c. TUBES LIMITED, BIRMINGHAM. O8179

YARROW & CO. (1922), LTD., GLASGOW. PASSENGER AND CARGO STEAMERS, SHALLOW DRAFT VESSELS. 818

Campbells & Hunter, Ltd. SPECIALISTS IN Drillers & Boring Machinery for Engine Works and Boiler Shops. DOLPHIN FOUNDRY, LEEDS. 4547

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Cochran MULTITUBULAR AND CROSS-TUBE TYPES Boilers. See page 17, April 20. 1134

The Mitchell Conveyor and TRANSPORTER CO., LTD., CONTRACTING ENGINEERS. DESIGNERS and BUILDERS of all Classes of HANDLING MACHINERY. Atlantic House, 45-50, Holborn Viaduct, London, E.C 1. Telegrams: "Micontraco, Cent, London." Telephone: Holborn 2822. 987

The Glasgow Railway Engineering Company, GOVAN, GLASGOW. LTD., London Office—12, Victoria Street, S.W. MANUFACTURERS OF RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES. CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 1234

Suitable for Light Railway, Tramway and General Power Transmission. A complete GENERATING PLANT of 1000 Kw. capacity is available for immediate delivery, comprising two 500 Kw. high-speed, enclosed, Compound Engines and Dick-Kerr Dynamos, 500-550 Volts D.C., Allen's Surface Condensing Plant, Edwards' and other Pumps, Baker Separator, piping, valves, &c., complete. Very low price—excellent condition. Also DIESEL ENGINES, 850/1200 HP. JENNINGS, West Walls, Newcastle-on-Tyne. 978

P. & W. MacLellan, Ltd., CLUTHA WORKS, GLASGOW. MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION. RAILWAY IRONWORK, BRIDGES, ROOFING, &c. Chief Offices: 129, Trongate, Glasgow. Od 3547 Registered Offices: Clutha House, 10, Princes St., Westminster, S.W. 1.

See's Patent Hydro-Pneumatic Ash Ejector. Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4325

Iron and Steel Tubes and Fittings. Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817

The Scottish Tube Co., Ltd., HEAD OFFICE: 34, Robertson Street, Glasgow. See Advertisement page 69.

Royles Limited, ENGINEERS, IRLAM, MANCHESTER. FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM and GAS KETTLES, } Row's Patents. Merrill's Patent TWIN STRAINERS for Pump Suctions. SYPHONIA STEAM TRAPS, REDUCING VALVES High-class GUNMETAL STEAM FITTINGS. WATER SOFTENING and FILTERING. 5723

IRON & STEEL Tubes AND Fittings AND Steel Plates.

Stewarts and Lloyds, Ltd. GLASGOW - BIRMINGHAM LONDON. See Advertisement Page 102. 1111

Drag Line Excavator. Has moved 2,000 cube yards in one day. May be seen at Frodsham, near Chester. Reach 77 ft.; lift four to five tons; speed of working, one to three cuts a minute. HARRY FAIRCLOUGH, Contractor, WARRINGTON. 1107

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John Kirkaldy, Ltd., London Office: 101, LEADENHALL ST., E.C. 3. Works: BURNT MILL, near HARLOW, ESSEX. Makers of Evaporating and Distilling Plants. Refrigerating and Ice-making Machinery. Feed Water Heaters. Evaporators. Fresh Water Distillers. Main Feed Pumps. Combined Circulating and Air Pumps. Auxiliary Surface Condensers. &c., &c. 846

E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidising, London."—Great Eastern Road, Stratford, E. 15. 1794

Designs, Production DRAWINGS, TRACINGS, etc. Prepared for all kinds Engineering work. Patent Drawings. J. HAMMOND, 63, Summer Road, East Molesey, Surrey. 'Phone: Esher 341. 1273

THE GLASGOW ROLLING STOCK AND PLANT WORKS. Hurst, Nelson & Co., Ltd., Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK. Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH-WORK, IRON & BRASS CASTINGS. PRESSED STEEL WORK OF ALL KINDS. Registered Office and Chief Works: Motherwell. London Office: 14, Leadenhall Street, E.C. Od3382

MACHINE-CUT D.B.S. GEARS of every description. 1440

David Brown & Sons (Hudd.) Ltd, Lockwood - - - - - Huddersfield.

For Your Repairs or any SPECIAL MACHINERY, try—THOMAS HUNT & SONS, Albion Ironworks, Bridge Road West, Battersea, S.W. 11. Est. 1854. 1313

Carels Diesel & Steam Engines. 1120 CARELS DIESEL & STEAM ENGINES (LONDON), LTD., Carlton House, Regent Street, London, S.W. 1. Telephone: Regent 3484.

YARROW & CO. (1922), LTD., GLASGOW. LAND AND MARINE YARROW BOILERS. 819

John Bellamy Limited, MILLWALL, LONDON, E. GENERAL CONSTRUCTIONAL ENGINEERS. 1216 Boilers, Tanks & Mooring Buoys STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

RAILWAY AND TRAMWAY ROLLING STOCK. Hurst, Nelson & Co., Ltd., THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3382

Head, Wrightson & Co., LIMITED. See Advertisement page 56, April 20. 2402

Powering of Vessels.—A Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 1049, Offices of ENGINEERING.

Phone—Holb. 541. Tele.—Andrubo, Holb., London. Andrews & Beaumont, CHARTERED PATENT AGENTS, 1292 29, Southampton Buildings, London, W.C. 2.

General Smiths' Work. FELLOWS BROS., LTD., 9158 CRADLEY HEATH, STAFFS.

Railway Switches and Crossings. T. SUMMERSON & SONS, LIMITED, DARLINGTON. 1312

GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED Duckham's Patent Suspended WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c. See Illus. Advt. last week, page 15. 991

WAYGOOD-OTIS LIFTS 710 54 & 55, FETTER LANE, LONDON, E.C.4, 62 & 63, LIONEL STREET, BIRMINGHAM, and Principal Provincial Cities and Abroad.

Petter Oil Engines. For Paraffin and Crude Oil Sizes 1½ B.HP. and upwards. Petters Limited, Yeovil. Sizes 25 to 500 B.HP. Vickers-Petters, Ltd., Ipswich See advertisement alternate weeks. 9235

Centrifugals. Pott, Cassels & Williamson, MOTHERWELL, SCOTLAND. 999 See half-page Advertisement, page 63, April 13.

The Manchester Steam Users' Association.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

Battersea Polytechnic,

London, S.W. 11.
PRINCIPAL: ROBERT H. PICKARD, D.Sc., F.R.S.

SPECIAL EVENING REVISION COURSES in the undermentioned subjects will commence the week beginning May 7th:—
Strength of Materials and Theory of Structures.
Hydraulics and Theory of Heat Engines.
Theory of Machines.
Electrical Technology.
These classes are suitable for the Final Examination for the B.Sc., Engineering, or the Associate Membership Examinations of the Inst. C.E., Inst. M.E., Inst. E.E., etc.
Also a Course of Seven Lectures on Ferro-Concrete Design, commencing May 7th.
For further particulars of above and other classes, apply to the PRINCIPAL. A 282

Correspondence Courses for

Inst. Civil Engrs., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by Mr TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1295

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

Engineering Examinations.—

Day, Evening, or Correspondence Courses of Preparation for all Examinations. Thousands of successes during the past eighteen years.—G. P. KNOWLES, M.B.E., B.Sc., A.M.I.C.E., etc., 39, Victoria street, Westminster, S.W. 1. A 349

TENDERS.

BIDEFORD BRIDGE TRUST.

WIDENING OF BIDEFORD BRIDGE.

Tenders are Invited for the

RECONSTRUCTION of the MASONRY CUTWATERS and FOUNDATIONS of BIDEFORD BRIDGE, and for the WIDENING of the ROADWAY in Reinforced Concrete.

Specifications and drawings may be seen at the offices of the Bridge Steward, 24, Bridgeland Street, Bideford, and at the Offices of Sir DOUGLAS FOX AND PARTNERS, 28, Bedford Place, London, W.C. 1, on and after Monday, April 30th, 1923. Copies may be obtained at a charge of 15s., which is not returnable.

Sealed Tenders must be submitted to the Bridge Steward not later than noon, May 22nd, 1923.

The Trust do not bind themselves to accept the lowest or any Tender.

H. M. BAZELEY,
Steward to the Bridge Trust.
24, Bridgeland Street, Bideford. A 312

TEDDINGTON URBAN DISTRICT COUNCIL.

SUSPENSION BRIDGE.

The above Council Invite

Tenders for Works in Con-

nection with the REPAIR of the SUSPENSION BRIDGE across the River Thames at Teddington.

Plans and Specifications may be seen at the offices of Messrs. MOTT, HAY & ANDERSON, of No. 9, Idlesleigh House, Caxton Street, Westminster, S.W. 1, where a form of Tender may be obtained after payment of a deposit of Five Guineas to the undersigned, which will be returned on receipt of a *bona fide* Tender.

Sealed Tenders, endorsed "Tender for Suspension Bridge Repairs," to be delivered to the address hereunder not later than the 4th May 1923.

The Council do not bind themselves to accept the lowest or any Tender.

G. H. SALMONS,
Clerk to the Council,
Council Offices,
Teddington.
20 April, 1923. A 293

TYNE IMPROVEMENT COMMISSION.

POLICE STEAM LAUNCH.

The Tyne Improvement Commissioners are prepared to receive

Tenders for the Construction

and DELIVERY in the Tyne of a SINGLE SCREW STEAM LAUNCH, about 57 feet long, 11 feet beam, speed 11 or alternatively 13 knots, with cabin and crew accommodation, etc.

Copies of the Form of Tender, Conditions of Contract, General Specification and outline drawing may be obtained from this Office on payment of a deposit of £2 2s. which will be returned on receipt of a *bona fide* Tender.

Tenders in sealed envelopes endorsed "Tender for Steam Launch" must be delivered at the undermentioned Offices addressed "The Chairman, Collision Sub-Committee," not later than Noon on the 25th day of May, 1923.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By Order,
ALBERT BLACKLOCK,
Secretary.
Tyne Improvement Commission Offices,
Bewick Street,
Newcastle-upon-Tyne,
23rd April, 1923. A 316

CITY OF LEICESTER.

NORTH BRIDGE WIDENING.

The Highways and Sewerage Committee of the Corporation of Leicester are prepared to receive

Tenders for the Widening of

the NORTH BRIDGE over the River Soar, between Freg Island and Woodgate; comprising the Extension of the Masonry Piers, Abutments and Foundations, with Cofferdams; and for the SUPPLY and ERECTION of STEEL PLATE GIRDERS, STEEL TROUGHING, and for other works in connection therewith.

Drawings and General Conditions may be seen and Copies of Specification and Bills of Quantities obtained at the City Surveyor's Office on and after Monday, April 23rd, 1923, on payment of the sum of £2 which will be returned on receipt of a *bona fide* Tender. Cheques, etc., to be made payable to the Leicester Corporation.

Sealed Tenders on the Form supplied, addressed to the Chairman of the Highways and Sewage Committee, Town Hall, Leicester, are to be delivered not later than Twelve noon on Wednesday, 9th May, 1923, endorsed "Tender for North Bridge Widening."

The Committee do not bind themselves to accept the lowest or any Tender.

E. GEORGE MAWBEY, M.Inst.C.E.,
City Engineer and Surveyor.
Town Hall,
Leicester.
16th April, 1923. A 256

DEPARTMENT OF PUBLIC WORKS,

Sydney, 31st January, 1923.

SYDNEY HARBOUR BRIDGE TENDERS—EXTENSION OF TIME.

Tenders are Invited by

the Government of New South Wales for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF A CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1000 feet in the clear, centre to centre of main piers, and a length of main bridge 2600 feet centre to centre of anchor piers. The total length of main bridge and approach spans included in tender is 3810 feet; also an ALTERNATIVE TENDER for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF AN ARCH BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear centre to centre of bearings. The total length of main bridge and approach spans included in tender is 3770 feet. Either bridge is to provide for four lines of railway, six lines of vehicular traffic, and footway accommodation.

Copies of Specification, including Plans, Technical Information, General Conditions, and Tender Forms, may be obtained by *bona fide* tenderers on application to the Under Secretary for Public Works, Sydney, or to the Agent-General for New South Wales, Australia House, The Strand, London; the Minister of Railways and Canals, Ottawa; The Australian Trade Commissioner in the United States, New York; or the Bureau of Foreign and Domestic Commerce, Washington, D.C., United States.

Tenders, the time for which has been extended, must reach the Under Secretary for Public Works Sydney, New South Wales, not later than 30th November, 1923.

R. T. BALL,
Minister for Public Works and Railways. A 59

MIDLAND GREAT WESTERN RAILWAY OF IRELAND.

CONTRACTS FOR 1923.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Supply of the

undermentioned STORES. The Contracts to commence from the 1st of July next, and to be for six months.

	No. of Form.		No. of Form.
Barrows and Trucks	2	Locks, Rainwater Goods & Hardware	25
Baskets and Mats	3	Paints, Colours and Wallpaper	27
Brushes, Brooms, &c.	4	Ropes and Canvas	28
Brass Fittings for Gas and Water	5	Screws, Split Pins, Nails, &c.	31
Bolts, Nuts and Rivets	6	Sheet Tin, Lead, Gun Barrel, &c.	32
Bricks, Slates, Earthenware Pipe, &c.	7	Steel Tyres, Axles and Plates	33
Chain	8	Ingots	34
Cement	9	Steel & Copper Tubes, Copper Plates and Steel Castings	35
Candles and Soap	10	Staffordshire Iron, Wire, &c.	36
Carriage Fittings	11	Springs, Steel, and Files	37
do. Trimmings	12	Soft Goods	38
Clothing	12a	Tools	40
Creosote Oil	13	Tool & Barrow Shafts	41
Drysalteries	14	Varnishes	42
Fog Signals	15	Wagon Covers and Tarpaulins	43
Farm Produce Boxes	15a	Waste and Wicking	44
Glass	16	Yorkshire Iron	45
Gas Mantles, &c.	18		
Iron and Steel Forgings	19		
Iron Castings	20		
Lime	24		
Leather and Belting	23		
Lamps and Tinware	24		

Forms of Tender can be obtained, on payment of 6d. each, from the STOREKEEPER, GENERAL STORES DEPARTMENT, BROADSTONE STATION, DUBLIN. *Stamps will not be accepted.*

Patterns and Samples can be inspected at the same place on and after 7th prox., between the hours of Ten a.m. and Four p.m. (Saturday, Ten a.m. to Twelve noon).

Contractors cannot be allowed to tender to supply goods to their own patterns, nor can the Company's patterns be sent away for inspection.

The Directors will not consider any Tender unless furnished on the Company's forms; nor any Tender in which any alteration of the form has been made.

The Tenders to be sent in by post, sealed and endorsed on the envelope, "Tender for Stores, Form No. ——," and addressed to "The Chairman, Broadstone Station, Dublin," so as to reach him on or before Ten a.m. on the 21st May.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order,
PERCY A. HAY,
Secretary.
Broadstone Station, Dublin,
April, 1923. A 336

STATE ELECTRICITY COMMISSION OF VICTORIA.

AUSTRALIA.

Tenders are Invited for

the MANUFACTURE, SUPPLY, DELIVERY and SUPERINTENDENCE of ERECTION of the following:—

SPECIFICATION No. 23/63.

ELECTRICALLY OPERATED POWER SHOVEL.

Tender forms, Specification, Contract Conditions, etc., are available upon application to

AGENT-GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C. 2.

The charge per one set of two copies of the Specification is £1 which will be refunded on receipt of a *bona fide* Tender and the return of all documents supplied.

Tenders on prescribed forms accompanied by a deposit of £50 and endorsed "SPECIFICATION 23/63 — ELECTRICALLY OPERATED POWER SHOVEL," will be received up to Noon on the 31st July, 1923, by

R. LIDDELOW,
Secretary,
State Electricity Commission of Victoria,
22-32, William Street, Melbourne.

The Commission does not bind itself to accept the lowest or any Tender. A 253

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely:—

	Fee for Specification.
STEEL AXLES (Forgings) for Carriages and Wagons	10s.
PLATELAYERS' TOOLS	10s.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steel Axles," or, as the case may be, not later than Eleven o'clock a.m. on Tuesday, the 8th May, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, E.C. 2.
London,
26th April, 1923. A 346

CITY OF BRADFORD.

The Bradford Corporation invite

Tenders for the Supply,

DELIVERY, COMPLETE ERECTION and SETTING TO WORK of:—

CONTRACT "R. 218."—One 15,000/20,000 Kw. THREE-PHASE TURBO-GENERATOR, &c. (without Condensing Plant, which will be the subject of a separate contract).

Tenders must be for the whole of the work included in the Contract.

Copies of the Specification, Conditions of Contract, Form of Tender, &c., may be obtained from Mr. THOMAS ROLES, M.I.E.E., City Electrical Engineer and Manager, Electricity Offices and showrooms, 45 to 53, Sunbridge Road, Bradford, on payment of the sum of one guinea. Additional copies of the Specification, &c., may be obtained on payment of the sum of half-a-guinea per copy. The sums paid will only be refunded upon receipt of a *bona fide* Tender, with the return of all the documents in good condition, and after the Tenders have been adjudicated upon.

Sealed Tenders, on the Forms provided, must be sent, fully filled in, to me not later than Ten a.m., on Thursday, the 7th June, 1923, endorsed "Tender for Electricity Works—Contract 'R. 218.'"

The Contract will be let subject to the Fair Contracts Clauses of the Corporation, which may be seen at the Town Clerk's Office, and which the accepted Contractor will be required to sign.

The lowest or any Tender will not necessarily be accepted.

N. L. FLEMING,
Town Clerk.
Town Hall,
Bradford.
24th April, 1923. A 333

METROPOLITAN BOROUGH OF SHOREDITCH.

ELECTRICITY SUPPLY DEPARTMENT.

The Shoreditch Borough Council have

For Disposal certain Old Plant,

including the following:—

One 165 Kw. Willans B.C.C. Direct Coupled GENERATOR, 160 volts, D.C.
Four 120 Kw. MOTOR TRANSFORMERS, with certain H.T. Switchgear.
Four 66 Kw. MOTOR TRANSFORMERS.
Four 33 Kw. MOTOR TRANSFORMERS.
One STEAM SUPERHEATER (partly dismantled).

Applications to view the plant should be made to the undersigned, from whom more detailed information can also be obtained, including Conditions of Sale, etc.

Tenders are to be made on the official forms (provided upon application), and are to be delivered by not later than Noon on Tuesday, the 8th May, 1923 (Signed) C. NEWTON RUSSELL,
Borough Electrical Engineer.
Electricity Supply Department,
Coronet Street, Shoreditch, N. 1.
26th April, 1923. A 347

APPOINTMENTS OPEN.

Works Manager Wanted for

Engineering Works and Foundry, specialising in heavy non-repetition work, i.e., Reversing Rolling Mill Engines, Large Gas Engines, Uniflow and other Steam Engines, &c. Must be capable organiser with foundry experience.—Address, stating age, experience, salary required, "THE GENERAL MANAGER, GALLOWAYS, LTD., Knott Mill Ironworks, Manchester," marking envelopes "Works Manager." A 330

General Manager Wanted for

Burma, for Engineering Works and Stores there, doing general engineering business. Term of engagement under agreement.—Address, stating age, qualifications and train ng, and salary expected. A 303, Offices of ENGINEERING.

Wanted, Rate Fixer for Tool

Room, in Automobile Firm in Midlands. Experienced men only considered.—Address, A 297, Offices of ENGINEERING.

Ratefixer Wanted, with Wide

Experience in Switchgear Assembly Operations. Only competent and highly trained men possessing substantial experience of this class of work will be considered. Good prospects for suitable man. State age, details of training and experience, and salary required.—Address, A 299, Offices of ENGINEERING.

Superintendent Engineer

WANTED for Oil Company owning large fleet of Tankers (Steam & Diesel).—Write stating age, qualifications, experience and salary required, BOX Y.Z., DORLAND Agency Ltd., 16, Regent St., S.W. 1. A 318

Heating Engineer Required

for Yorkshire Office. Must be competent to design modern systems of Heating, Ventilating Plants, etc. State age, experience and salary required.—Address, A 351, Offices of ENGINEERING.

Applications are Invited

for the post of ENGINEER TO TAKE CHARGE OF DESIGN.

Salary £300 rising by annual increments of £15 to £500 and full Civil Service Bonus.

Present Salary, including bonus:—
£440 16s 10d.

The Bonus corresponds to a cost of living index figure of 80 per cent., and is subject to an increase or decrease by 1/4th for every five points rise or fall in the index figure.

The post will carry Superannuation Benefits under the Federated Superannuation Scheme for Universities.

The candidate should possess good technical qualifications, a degree or diploma in Engineering being desirable. Experience in Engineering Design for Automobile or similar work is essential. A general knowledge of Engineering Shop practice and production methods will be taken into consideration.

Applications should be made to the SECRETARY OF THE ADMIRALTY (C.E. Branch), London, S.W. 1. A 331

Applications are Invited by

Manchester Engineering Firm for the POSITION of DRAUGHTSMAN with good General Engineering knowledge and experience, and familiar with Steam Plant, Pipework lay-out, and details. Age 24/40. Electrical experience an advantage. State age, experience and salary required.—Address, A 258, Offices of ENGINEERING.

Wanted, First-class Draughts-

MAN, thoroughly conversant with MACHINE CUT GEARING and its APPLICATION. Apply, stating age, full experience and salary required. Only competent men need apply.—DAVID BROWN & SONS (Huddfd.) Ltd., Park Gear Works, Lockwood, Huddersfield. A 343

Draughtsman Required, ex-

perienced in Rotary Printing Press work.—Write full particulars, R. HOE & CO., LTD., 167, Borough Road, London. A 308

Required, Competent Civil

ENGINEERING DRAUGHTSMAN, familiar with Dock Work, for Humber District. Salary £300. —Address, stating age, experience and full particulars, A 340, Offices of ENGINEERING.

Machine Tool Draughtsman

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THE DESIGN OF HOT-AIR DRYING PLANT.

By GEORGE H. GILL.

MODERN hot-air drying plant may be divided into two main classes:—(1) Batch dryers in which a batch of material is loaded into a compartment or chamber where it remains under the action of heated air until dry. The batch is then removed, the compartment reloaded and the operation repeated. (2) Continuous or progressive dryers in which the wet material enters at one end and is carried through the apparatus or "Tunnel" on trucks or conveyors, where it is subjected to the action of heated air, leaving when dry at the opposite end.

Batch drying rooms vary considerably in dimensions, but from an economical point of view, it is desirable to subdivide the dryer into a number of compartments each, say, about 18 ft. by 10 ft. by 6 ft. 6 in. high. A better air distribution can be secured by this treatment, and each section of the dryer may be shut off in rotation for loading or discharging. It is usual to arrange for the heated air to enter at one end of the chamber at the floor level, under pressure from a fan, and to leave at the front of the dryer at high level, or, alternatively, through slots in hollow side walls.

Continuous dryers of the tunnel type are of various lengths, from 30 ft. to 120 ft., the width and height varying according to the material to be dried. They may be subdivided into three classes according to the relative direction of travel of air and material: (1) The most usual type is that in which the air and material travel in inverse directions. Heated air is admitted at the end where the dry material leaves the tunnel and is exhausted at the opposite end where the wet material enters. (2) In comparatively recent years, dryers have been manufactured in which the air and material travel in the same direction through the tunnel. Cold air enters with the wet material and is gradually heated by a series of specially-arranged heaters during its passage through the dryer. The air is exhausted hot and moist at the end where the dry material leaves. (3) Both of the foregoing types have the disadvantage that the material, together with the cars which carry it, leave the dryer hot, thus causing a loss in heat. On the Continent, there are now many continuous dryers at work on the general inverse principle, but with the difference from usual practice that cold air enters at the end where the dry material leaves. As in type (2), the air is gradually heated up by special heaters in passing through the dryer and is exhausted hot and moist at the end where the wet material enters.

For practical purposes the heat units necessary to raise the moisture in the material to ordinary dryer temperatures and evaporate it, may be taken to be 1,100 B.Th.U. per pound. The real efficiency of a dryer is the ratio of this to the total heat supplied per pound of moisture. Dryers of the compartment type and the first type of continuous dryer described are found to give an efficiency of from 40 per cent. to 55 per cent. Type (2) will be found to give about 64 per cent., whilst the third type attains 66 per cent. to 67 per cent., as an additional economy is obtained by the heating of the inlet air by the cooling of the material and cars leaving the apparatus.

Some authorities calculate the efficiency on a basis of the ratio of heat absorbed in heating material plus heat to evaporate moisture to total heat supplied. In view of Type 3 above it will be seen that this method cannot be universally applied and is therefore not rational.

In all types of hot air drying apparatus, the air supplied must fulfil two functions: (1) It must convey the necessary heat for the evaporation of the moisture in the material to be dried, plus the heat losses of the dryer. (2) It must absorb and carry away the moisture thus evaporated.

The total heat to be supplied is made up of the following items:—(1) Heating trucks or conveyors carrying the material in the dryer; (2) heating the walls of the dryer, if used intermittently; (3) heating the substance of the wet material; (4) evaporating the moisture in material; (5) radiation loss from walls of dryer; (6) leakage loss at doors, &c., of dryer; (7) heat carried away in exhaust air.

Items (1) to (6) constitute what we shall call later the heat absorbed in the dryer. Item (7) is often of large proportions, and the main reason for the increased efficiency of the two more recent types of continuous dryers mentioned, is on account of the reduction in the heat loss at exhaust, which is only from 10 per cent. to 15 per cent. of the total heat supplied as compared with 30 per cent. to 40 per cent. in dryers of the ordinary inverse type.

Table I gives the weight of moisture in grains which can be absorbed by 1 lb. of dry air to saturation. It will be noted that there is a tremendous increase in the capacity of air for moisture as the temperature is raised to quite moderate values. In the ordinary inverse type of dryer, it is not advisable to increase the percentage of saturation of the air at exhaust above about 66 per cent. owing to the liability of condensation of its moisture on the incoming wet material.

Saturation of 75 per cent. can be obtained with the later types of apparatus as this trouble is absent, and when Table I is studied, it will be seen that the weight of air necessary to carry away the moisture at from 140 deg. to 180 deg. F., and 75 per cent. saturated is only a fraction of that required to carry the same quantity at from 80 deg. to 100 deg. F., and 66 per cent. saturated, as is usual practice in the inverse type or the compartment type of dryer. One pound of air at 180 deg., and 75 per cent. saturated can carry about 3,400 grains of moisture, whilst 1 lb. of air at 80 deg. and 66 per cent. saturated can only carry about 103 grains of moisture. The fact that the air is exhausted at 180 deg., a comparatively high temperatrue, is more than counterbalanced by the small weight of air required to carry the moisture, and the loss at exhaust is therefore extremely low.

The highest possible dryer efficiency can only be secured when the fans for circulating the air carrying the heat to the material are separate from that used to remove the air after it has absorbed the moisture. It is also essential that a rapid circulation of air inside the dryer is provided and the material should leave the dryer cooled down and dry.

TABLE I.

Temperature, Deg. F.	Grains. Moisture per Lb. of Air at Saturation.	Temperature. Deg. F.	Grains Moisture per Lb. of air at Saturation.
32	26·5	88	204·0
40	36·4	89	211·0
50	53·5	90	218·0
60	77·0	91	225·0
65	93·0	92	232·0
70	110·0	93	240·0
71	114·0	94	247·0
72	118·0	95	256·0
73	123·0	96	265·0
74	127·0	97	274·0
75	131·0	98	282·0
76	136·0	99	292·0
77	141·0	100	301·0
78	146·0	105	354·0
79	151·0	110	410·0
80	156·0	115	480·0
81	161·0	120	565·0
82	167·0	130	770·0
83	172·0	140	1,060·0
84	178·0	150	1,480·0
85	184·0	160	2,150·0
86	191·0	170	3,000·0
87	197·0	180	4,550·0

Construction of Dryers.—It is important from the point of view of efficiency that the heat loss from the dryer by radiation is kept to a minimum.

The heat loss in B.Th.U. per hour by radiation is given by:—

Surface in square feet × Mean temperature difference internal and external × Coefficient of transmission.

It is sufficiently accurate to calculate the mean temperature difference as

$$\left\{\frac{\text{Inlet} + \text{Outlet}}{2} - \text{External air}\right\}$$

and the coefficient of transmission for walls, roof, &c., can be obtained from Table II. This table gives values in British thermal units per square foot, per degree per hour for various materials used in dryer construction. Each surface must be calculated separately using the internal dimensions.

Tunnel dryers working in the open are usually constructed with 14-in. outside walls and with reinforced concrete roof. If constructed inside a building, they may be built of double 1-in. boards with sawdust filling or of sheet iron panels on angle iron framework insulated with cork board. The latter arrangement is very neat and satisfactory. Well fitting counterbalanced doors are necessary.

TABLE II.

Material.	Coefficient.	Material.	Coefficient.
Brick wall, 4½-in.	0·50	Roof tiles, 1 in.	0·80
Brick wall, 9-in.	0·36	Pine board, ¾-in.	0·77
Brick wall, 14-in.	0·28	Pine board, 1-in.	0·51
Brick wall, 18-in.	0·25	Double 1-in. boards with 2 in sawdust between	0·13
Concrete walls or roof of same thickness as above, at 30 per cent. greater transmission.		Sheet iron with 1 in. corkboard insulation	0·30
		Wooden door, 1¼-in.	0·32

The rail track may be 20-in. or 24-in. gauge made up of rails weighing 12 lb. per yard, and the tunnels are usually made with a slope of 1 in 60 to 1 in 100 in the direction of travel of trucks. Suitable turntables at each end and return track rails outside must be provided. The trucks must be pushed through the tunnels as they are not usually provided with couplings, and this may be accomplished by means of a winch operated by manual labour. Suitably arranged pulleys and wire rope will enable the ingoing truck to be pushed into the tunnel. Drying tunnels are at work having no slope and fitted with various mechanical devices to move the trucks. This, of course, adds to the expense of the installation and is not absolutely necessary.

It is important that a short circuit of air from end to end of the tunnel between wheels and under axles of trucks should be prevented. This space should be made up by a raised platform between rails just clearing the axles. Air may be delivered to the tunnel through a grating in the floor inside the door and leave by a similar grating in the floor at the opposite end. The exhaust air may then pass either to atmosphere *via* an outlet duct, or part may be returned to the fan chamber by means of a suitable duct arranged under the dryer and re-circulated. With average conditions and using a standard tubular steam heater to heat the air, the static water gauge required to be set up by the fan and the power necessary, would be as given in Table III.

TABLE III.

Length of Tunnel, Feet.	Static W.G. of Fan, Inches.	Fan B.H.P. required per 1,000 Cub. Ft. of Air per Minute.
Up to 25	1½	0·47
25 to 40	2	0·63
40 to 65	2½	0·785
65 to 85	3	0·945

RATE OF DRYING.

The time required to dry material depends upon: (1) Its nature and the rate at which it can give up its moisture; (2) the air velocity over the material; (3) the air temperature; (4) the percentage of saturation of the air current; (5) the final moisture content required.

(1) *Nature of Material.*—Materials in general may be divided into two classes: (*a*) Hard to dry—such as timber, bricks and fish, or any material liable to form a dry outer skin, thus closing the pores, while the interior is still moist. These require special treatment, and rapid drying in the preliminary stages is fatal to success. (*b*) Easy to dry—such as laundry goods, powders, cotton waste, cement sacks. As a general rule, the rate of evaporation from a material is approximately proportional to its ratio of surface to volume.

TABLE IV.

Air Velocity over Material, Feet per Minute.	Relative Rate of Evaporation.
750	0·545
1,000	0·728
1,250	0·865
1,500	1·0
1,750	1·18
2,000	1·41
2,250	1·73
2,500	2·09

(2) *Air Velocity.*—To dry a material in minimum time, the air velocity should be as rapid as is economically possible. Assuming 1,500 ft. per minute air velocity over a given material as unity,

the approximate relative rates of evaporation for varying air velocities are as given in Table IV.

(3) *Air Temperature.*—The temperature of air should be as high as possible without injurious effect on the material, such as discoloration, chemical change, &c., as its effect on the time to dry is very important. For a given material—other conditions being constant—the effect of change in temperature on rate of evaporation is approximately as follows :—

TABLE V.

Temperature.	Relative Rate of Evaporation.
90	1·0
100	1·5
110	2·0
120	2·5
130	3·4
140	4·45
150	5·7
160	7·3

(4) *Saturation.*—The percentage of saturation of air in the dryer also affects the time required to dry. Other conditions being constant, the effect on a given material is as follows :—

TABLE VI.

Mean Percentage of Saturation of Air.	Relative Rate of Evaporation.
20	1·0
25	0·95
30	0·87
35	0·81

(5) *Final Moisture.*—The time required to dry a material is largely affected by the final moisture content required. Some materials are considered to be dry when containing 10 per cent. or even higher final moisture, whereas certain chemicals must be carried down to 2½ per cent. or 1 per cent. For a given material, the relative time required to dry to various final moisture content is approximately as follows :—

TABLE VII.

Final Moisture Per Cent.	Relative Time to Dry.
10	1·0
7½	1·05
5	1·14
2½	1·25
1	1·62

The figures in the previous tables would form a suitable basis for further research, and the data given must be regarded as approximate only. However, they may form a valuable guide in case it is required to estimate the probable time to dry under certain altered conditions based on known results with a material. For example, suppose a certain material required 10 hours to dry in a dryer working at a mean temperature of 100 deg. F. at a mean dryer saturation of 25 per cent., and with an air velocity of about 1,500 ft. per minute. Now in a new installation it is proposed to work at a mean temperature of 110 deg. with mean saturation, say, 30 per cent., and an air velocity 1,750 ft. per minute, their estimated time to dry would be :

$$= 10 \times \frac{1 \cdot 5}{2 \cdot 0} \times \frac{0 \cdot 95}{0 \cdot 87} \times \frac{1}{1 \cdot 18}$$

(Tempr.) (Satn.) (Air velocity)

$= 10 \times 0 \cdot 75 \times 1 \cdot 09 \times 0 \cdot 848$

$= 6 \cdot 95$ hours—say, 7 hours.

For a material of the "easy to dry" type, this estimation will give a good indication of results to be expected. In the other case, the result is complicated by the rate at which moisture can be extracted from the interior.

(To be continued.)

THE VALIDITY OF THE LONDON ELECTRICITY SCHEME.

THE question of the validity of the London Electricity Scheme was discussed on April 12, 1923, in the King's Bench Division, before the Lord Chief Justice, Mr. Justice Avory and Mr. Justice Roche, in an application by some of the companies concerned for prohibition of the scheme, on the ground that in certain respects it is *ultra vires* of the Electricity Commissioners; but the court disposed of the application without giving a decision on the general question.

The Electricity (Supply) Act, 1919, provided for the setting up of a body called "The Electricity Commissioners," for the purpose of promoting, regulating and supervising the supply of electricity. They act under the general directions of the Ministry of Transport. They may provisionally determine that any district in the United Kingdom shall be constituted an electricity district for the purposes of the Act, but if any objections are raised they are to hold an inquiry before finally determining the area of the district. If it appears to them that the existing organisation for the supply of electricity in any such district should be improved, they are to hold a second inquiry, so that a scheme or schemes for the improvement may be submitted by those interested; and they have power to approve of a scheme, or themselves formulate one. The scheme may provide for the establishment of a joint electricity authority within the electricity district and for the transfer to such authority of the undertakings of authorised undertakers in the district, provided they consent to the transfer. The scheme is then to be published, and the Commissioners are to hold an inquiry regarding it—*i.e.*, a third inquiry. The next stage is the making of an order by the Electricity Commissioners, giving effect to the scheme. It is then to be presented to the Minister of Transport, who may confirm it, with or without modification, as he thinks fit. When confirmed, it is to be laid before each House of Parliament and is to become operative if and when approved by a resolution passed by each House.

In Greater London there were 60 or 70 different electricity undertakings when the Act of 1919 was passed, and it is not surprising that the Commissioners considered that the organisation of the electricity supply should be improved. After some preliminary procedure in terms of the Statute, schemes to this end were submitted. The public authorities desired a scheme constituting one joint electricity authority, and the London County Council were not prepared to transfer their powers unless there was one, and only one, such authority for the district. The private companies desired two authorities, one for the public authorities' areas, and the other for the companies' areas, and they refused to transfer their power stations and plant unless the companies retained the control. The Commissioners put forward a scheme which was now said by the companies to be *ultra vires*. It provided for one joint electricity authority for the whole area, to whom the London County Council would transfer their powers, but this authority was to constitute two committees to control respectively the companies' areas and the public authorities' areas under the supervision of the joint electricity authority. The question was whether the Commissioners had power to provide in the scheme that the joint electricity authority should be bound to delegate their powers in this way to the two proposed committees. Section 6 of the Act is to the effect that a scheme may provide for enabling a joint electricity authority to delegate any of its powers to committees, and it is to be a duty of every joint electricity authority to secure the provision of a cheap and abundant supply of electricity in their district and to comply with any general directions given to them by the Electricity Commissioners as to the exercise of their powers and duties. Apparently the companies' real object in applying to the court for prohibition of the scheme was not to get it prohibited or quashed, but to get a decision as to its validity before they incurred further expense in connection with it. The Lord Chief Justice said what was complained of was that the joint electricity authority was to be compelled, and not merely enabled, to delegate its powers to the two committees; but he pointed out that the scheme was still inchoate and had still to run the gauntlet of the Minister of Transport and of both Houses of Parliament; and without giving any decision as to its validity or invalidity the court refused to prohibit it at this stage. The companies therefore failed in their effort to get the question of its validity settled.

THE DESIGN OF PINIONS FOR GEARED TURBINES.

By RICHARD GARDNER.

H = horsepower.
N = revolutions per minute.
D = pinion diameter (inches).
L = tooth face (inches).
w = tooth pressure (lbs. per inch).
V = tooth speed (ft. per second).

THE greatest deflection of a pinion with a centre bearing is the deflection due to twist. Its magnitude is the deflection at the end where the twist is greatest *minus* the deflection at the middle. (We assume that w is uniform, hence the results we obtain must be regarded as comparative formulas.). Thus, greatest deflection =

$$A = \tfrac{1}{2} D \int_{\frac{1}{2}L}^{L} \frac{w x \cdot \frac{1}{2} D \cdot d x}{G J}$$

Modulus of rigidity $G = 12 \times 10^6$, and $J = \pi D^4 \div 32$, so that

$$A = \frac{w K^2}{4 \times \pi \times 10^6} \quad . \quad . \quad . \quad . \quad (1)$$

where $K = L \div D$.

From the deflection allowed in a number of successful installations, a deflection of 0·001 in. estimated in this way would appear to be a safe limit.

Putting in (1), $A = 0 \cdot 001$, and

$$w = \frac{126{,}000\,H}{N\,K\,D^2}$$

we obtain :

$$D^2 = 10\,K \frac{H}{N} \quad . \quad . \quad . \quad (2)$$

In the case of a pinion without centre bearing, it can be shown that the greatest deflection is A plus the maximum deflection due to bending. With the assumption of uniform tooth pressure, this deflection due to bending is

$$B = \frac{5}{8} \times \frac{1}{48} \times \frac{w L^4}{E I}$$

Taking Young's modulus $E = 30 \times 10^6$ and putting $I = \pi D^4 \div 64$, we have

$$B = \frac{w K^4}{36 \times \pi \times 10^6}.$$

Hence greatest deflection

$$A + B = \frac{w K^2}{4 \times \pi \times 10^6} \left(1 + \frac{K^2}{9}\right) \quad . \quad (3)$$

Making $A + B = 0 \cdot 001$, and substituting, as above, for w,

$$D^2 = 10\,K \left(1 + \frac{K^2}{9}\right) \frac{H}{N} \quad . \quad . \quad . \quad (4)$$

It was shown in ENGINEERING of October 13, 1922, page 453, that a safe value for abrading stress is

$$\frac{55 \cdot 55}{D} \sqrt{\frac{w^3}{V}} = 8{,}000 \text{ lbs. per sq. inch.}$$

on which basis

$$w = 27 \cdot 5 \sqrt[3]{V D^2}.$$

Putting $w = \frac{550\,H}{V\,L}$ and $L = K\,D$, this formula may be written :

$$D^5 V^4 = \left(20 \frac{H}{K}\right)^3 \quad . \quad . \quad . \quad . \quad (5)$$

Again, $V = \frac{N D}{229}$, so that from (5) :

$$D^3 N^{\frac{4}{3}} = 28{,}000 \frac{H}{K} \quad . \quad . \quad . \quad . \quad (6)$$

Our object is to determine D when the limits of deflection and abrading stress have been assigned.

For the case of a pinion with centre bearing, eliminate D between (2) and (6) :

$$10\,K \frac{H}{N} = \left(\frac{28{,}000}{N^{\frac{4}{3}}} \cdot \frac{H}{K}\right)^{\frac{2}{3}}$$

which reduces to

$$K^5 = 780{,}000 \frac{N^{\frac{1}{3}}}{H} \quad . \quad . \quad . \quad (7)$$

Thus K is found directly from the power and revolutions; D is then given by (6).

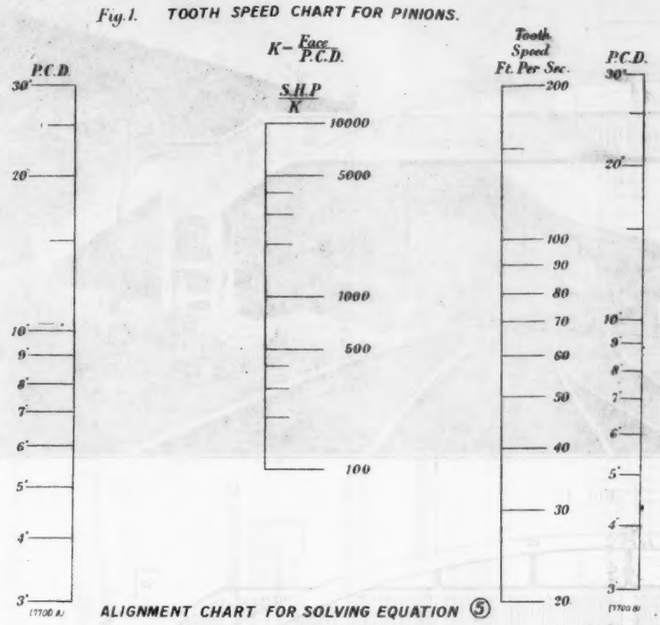
In the second case, where there is no centre bearing, D is to be eliminated between (4) and (6). The result is :

$$K^5 \left(1 + \frac{K^2}{9}\right)^3 = 780{,}000 \frac{N^{\frac{1}{3}}}{H} \quad . \quad . \quad (8)$$

The formulas (5), (6), (7) and (8) are best dealt with in the form of alignment charts, such as are represented in Figs. 1 to 4. The scales are, of course, logarithmic, except that of K in (8), where the scale is of

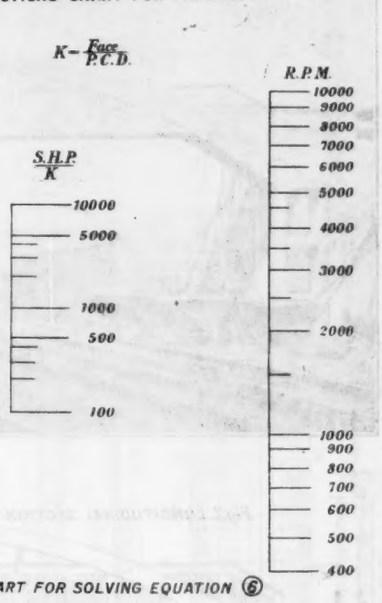
$$5 \log K + 3 \log \left(1 + \frac{K^2}{9}\right).$$

Fig. 1. TOOTH SPEED CHART FOR PINIONS.



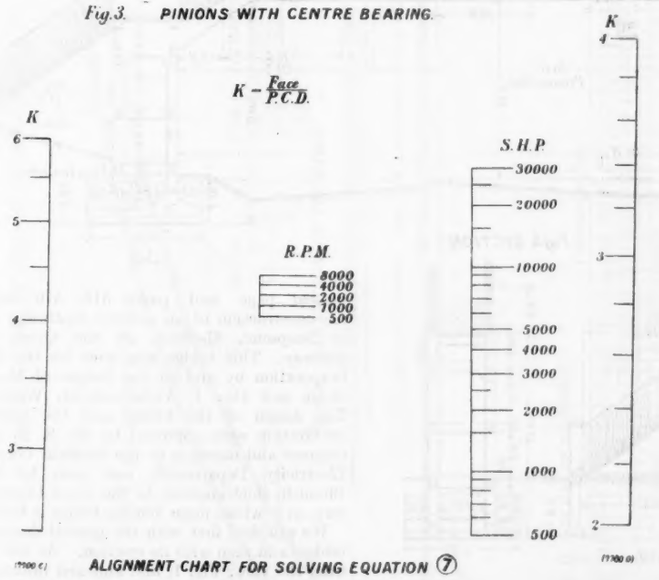
ALIGNMENT CHART FOR SOLVING EQUATION (5)

Fig. 2. REVOLUTIONS CHART FOR PINIONS.



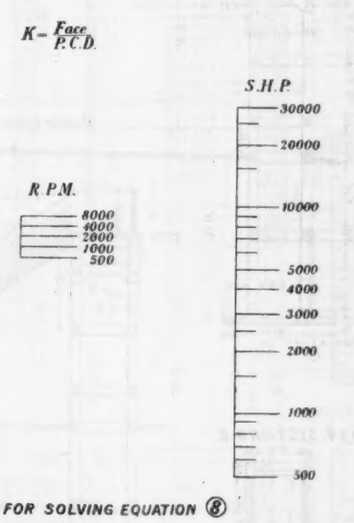
ALIGNMENT CHART FOR SOLVING EQUATION (6)

Fig. 3. PINIONS WITH CENTRE BEARING.



ALIGNMENT CHART FOR SOLVING EQUATION (7)

Fig. 4 PINIONS WITHOUT CENTRE BEARING.



ALIGNMENT CHART FOR SOLVING EQUATION (8)

From such charts, K or D is found by inspection when a straight edge is laid across the three appropriate scales.

The following example will show the method of design :—

A high-pressure turbine at 4,000 r.p.m. and a low pressure turbine at 1,600 r.p.m., each of 4,000 s.h.p., are to drive through double reduction gearing a propeller at 90 r.p.m. The main gear wheel is to be 130 in. diameter. The teeth are to be 0·628 in. circumferential pitch.

We have, for the secondary pinions, $V = 90 \times 130 \div 229 = 51$ ft. per second.

Assuming provisionally $K = 2 \cdot 5$ then from (5) $D = 22$ in., but this gives $N = 90 \times 130 \div 22 = 530$, and from (8) we find K may be as high as 2·9, say $K = 2 \cdot 8$. (5) then gives $D = 20$ in., and $N = 90 \times 130 \div 20 = 585$ r.p.m. The face length is $20 \times 2 \cdot 8 = 56$ in. The number of teeth in the pinion may be 100 if the wheel have 651 teeth, 130·2 in. p.c.d.

In the high-pressure gear, if the pinion have no centre bearing, then K, from (8), must not exceed 3·16. Using this value in (6), D = 8·3, but the tooth speed is then $4,000 \times 8 \cdot 3 \div 229 = 145$ ft. per second; hence the pinion must have a centre bearing, and (7) gives $K = 5$; from (6) we then have $D = 7$ in., thus reducing V to 122 ft. per second. Number of teeth = 35, face length = 35 in. The primary wheel has $35 \times 4,000 \div 585 =$ say, 242 teeth, 48·4 in. p.c.d.

The low-pressure pinion and wheel centres are usually the same as for the high-pressure pinion and wheel.

Wheel diameter + Pinion diameter = 48·4 in. + 7 in. = 55·4 in., and

$$\frac{\text{Wheel diameter}}{\text{Pinion diameter}} = \frac{1600}{585} = 2 \cdot 74$$

whence

$$\text{Pinion diameter} = \frac{55 \cdot 4 \text{ in.}}{3 \cdot 74} = 14 \cdot 8 \text{ in.}$$

and wheel diameter = 40·6 in.

From Fig. 2 $\frac{\text{s.h.p.}}{K} = 2,200$, or $K = 4,000 \div 2,200 = 1 \cdot 82$, therefore face length = $14 \cdot 8 \times 1 \cdot 82 = 27$ in. From (8), the limit of K is 3, so that a centre bearing is not required.

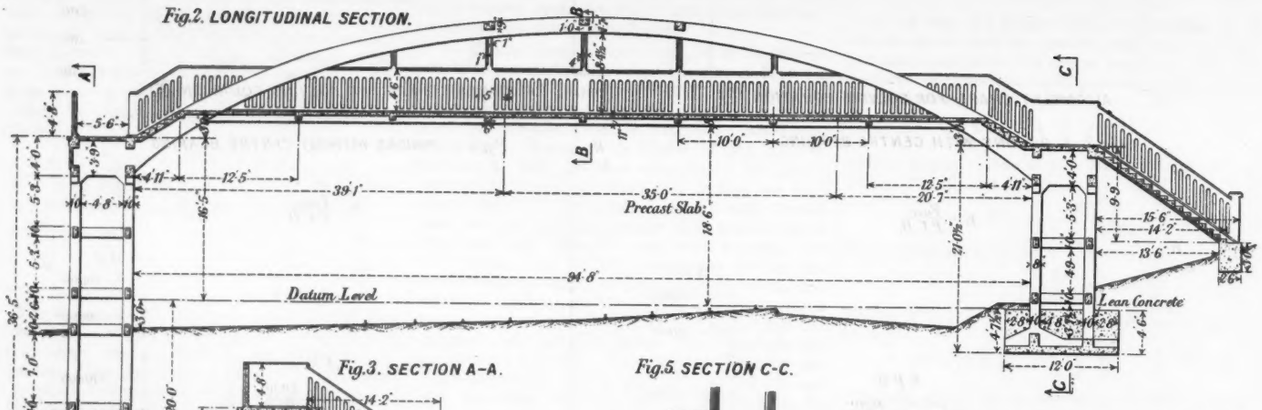
The design is then as shown in the table.

Gear.		H.P.	L.P.
Primary pinions	Teeth ..	35	74
	P.C.D. ..	7 in.	14·8 in.
	Face ..	35 in.	27 in.
	R.P.M. ..	4,051	1,607
Primary wheels	Teeth ..	242	203
	P.C.D. ..	48·4 in.	40·6 in.
	Face ..	35 in.	27 in.
	R.P.M. ..	586	586
Secondary pinions ..	Teeth ..	100	100
	P.C.D. ..	20 in.	20 in.
	Face ..	56 in.	56 in.
	R.P.M. ..	586	586
Main wheel	Teeth ..	651	
	P.C.D. ..	130·2 in.	
	Face ..	56 in.	
	R.P.M. ..	90	

REINFORCED-CONCRETE OVERBRIDGE AT NEEPSEND, SHEFFIELD.

CONSTRUCTED BY MESSRS. K. HOLST AND CO., ENGINEERS, WESTMINSTER.

FIG. 1.



REINFORCED CONCRETE FOOTBRIDGE AT NEEPSEND, SHEFFIELD.

THE objection is very often raised to the use of concrete work, either plain or reinforced, in railway structures, that the length of time required for setting would greatly inconvenience traffic in some of its possible applications. This point has been frequently referred to in connection with bridges which are made of concrete here less frequently probably than in any other of the more advanced European countries. In a good many cases in which concrete construction has been permitted various expedients have been resorted to in order to reduce possible inconvenience to traffic, and among these has been the practice of introducing into the structures pre-cast members. By this means in some cases headway has not been interfered with, while in others essential sections have been placed in position and the running lines blocked for a time no longer than would be required for steel structural work.

As an interesting example of the use of pre-cast parts, we illustrate in Figs. 1 to 43 on the present page, and pages 515, 516 and 526, the construction of an overline footbridge erected at Neepsend, Sheffield, on the Great Central Railway. This bridge was built for the Sheffield Corporation by and to the designs of Messrs. K. Holst and Co., 1, Victoria-street, Westminster. The design of the bridge and the method of its erection were approved by Mr. S. E. Fedden, engineer and manager to the Sheffield Corporation Electricity Department, and also by Mr. H. Blundell, chief engineer to the Great Central Railway, over whose main line the bridge is built.

We will deal first with the general design of the bridge, and then with its erection. As will be seen from the view, Fig. 1, and annexed drawings, the bridge is virtually a bow-string arch, though the horizontal chord does not span the whole arch. The railway is on a curve at the point where the bridge crosses it and the track is banked considerably. The minimum headroom provided under the bridge is 18 ft. 6 in., while the clear span is 94 ft. 8 in. Four tracks pass under the bridge, the two on the right hand (Figs. 1 and 2) being the main lines, while those on the left are sidings. The bridge is supported on two towers, each composed of four columns and bracing. Outside these towers staircases give access to the bridge, the one on the east side (right-hand in Fig. 1, &c.) being in line with the bridge, while that at the west end is turned through a right angle and descends parallel with the tracks. The deck of the bridge is integral with the horizontal chord of the arch, and is suspended from the arch members. At the ends of the horizontal chord a short

REINFORCED-CONCRETE OVERBRIDGE AT NEEPSEND, SHEFFIELD.

CONSTRUCTED BY MESSRS. K. HOLST AND CO., ENGINEERS, WESTMINSTER.

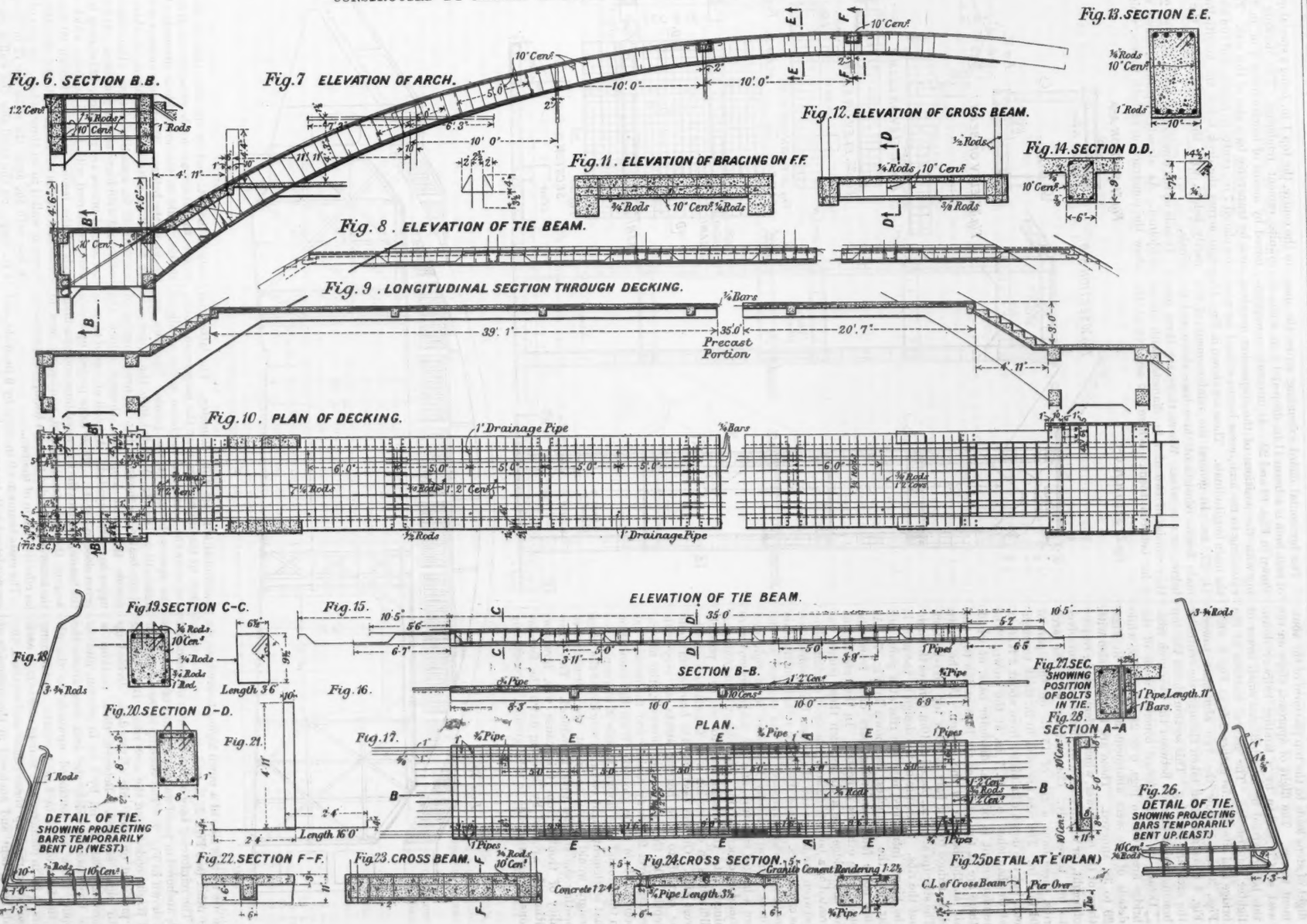


Fig. 6. SECTION B.B.
Fig. 7 ELEVATION OF ARCH.
Fig. 8. ELEVATION OF TIE BEAM.
Fig. 9. LONGITUDINAL SECTION THROUGH DECKING.
Fig. 10. PLAN OF DECKING.
Fig. 11. ELEVATION OF BRACING ON F.F.
Fig. 12. ELEVATION OF CROSS BEAM.
Fig. 13. SECTION E.E.
Fig. 14. SECTION D.D.
Precast Portion
1" Drainage Pipe
Fig. 15. ELEVATION OF TIE BEAM.
Fig. 16. SECTION B-B.
Fig. 17. PLAN.
Fig. 18.
Fig. 19. SECTION C-C.
Fig. 20. SECTION D-D.
Fig. 21.
Fig. 22. SECTION F-F.
Fig. 23. CROSS BEAM.
Fig. 24. CROSS SECTION.
Fig. 25. DETAIL AT 'E' (PLAN)
Fig. 26. DETAIL OF TIE. SHOWING PROJECTING BARS TEMPORARILY BENT UP. (EAST.)
Fig. 27. SEC. SHOWING POSITION OF BOLTS IN TIE.
Fig. 28. SECTION A-A
DETAIL OF TIE. SHOWING PROJECTING BARS TEMPORARILY BENT UP. (WEST.)
Length 3'6"
Length 16'0"
Concrete 1:2:4
Granite Cement Rendering 1:2½
C.L. of Cross Beam
Pier Over

flight of steps leads to the top platform of the abutment towers. The flight of approach steps on the west side is broken by a landing halfway down, this being carried by an additional small tower of lighter construction. The general features of the bridge and site may be gathered from Fig. 2, while Figs. 3 and 5 show the two abutment towers, Fig. 4 gives a section taken through the centre of the arch and decking. This section shows the top bracing which extends between the two arch ribs.

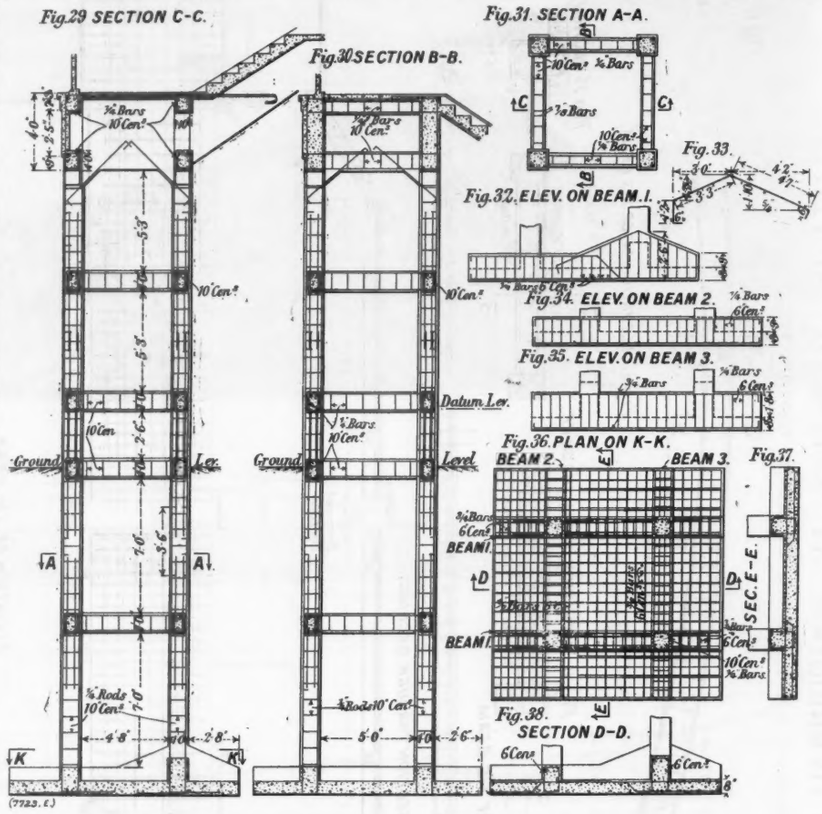
Details of the reinforced concrete work of the bridge are given in Figs. 6 to 28, page 515, while details of the west abutment are given in Figs. 29 to 38, annexed. These are identical also with those of the east tower, which differs only in respect of height, for which reason we shall confine ourselves to one tower only. Commencing with the arch ribs, these have a rise of 15 ft. on the span of 94 ft. 8 in. The ribs are each 10 in. thick throughout, but the depth diminishes from about 2 ft. 6 in. at the haunches to 1 ft. 7 in. at the crown. The reinforcement is of 1 in. diameter bars, of which there are at the haunches six bars at the top and six at the bottom of the section. At the crown these reduce to four bars at both top and bottom. The stirrups are $\frac{1}{2}$ in., placed at 10in. centres throughout the ribs. A feature of the design of the arch is the hinges introduced into the ribs at a point not far from the haunches, as shown in Fig. 7. At this point four reinforcing bars cross from one side to the other as indicated. In the calculations for the bridge the arch between these points was treated as a bow-string arch, the short continuations between the hinges and the towers being considered as cantilevers. When it came to actual construction preference was expressed by the engineer of the Great Central Railway Company for a rigid and not a hinged structure, and the hinge sections were therefore concreted in. The object of introducing hinges into the design was to get over possible difficulties in connection with foundations on the west side. On the east side the foundation could be carried to good bearing strata at very little depth. On the other side, however, the natural ground level fell away rapidly and the railway has been built on made ground. With the foundation in this ground on a sloping hillside it was considered that settlement might occur, in which case the hinge design would serve to assist the structure in meeting the stresses thus introduced. The possibility of trouble from this cause was, however, ultimately avoided by carrying down the foundations on the west side to solid ground, necessitating the use on this side of a much higher tower than on the other (see Figs. 2, 3, &c.).

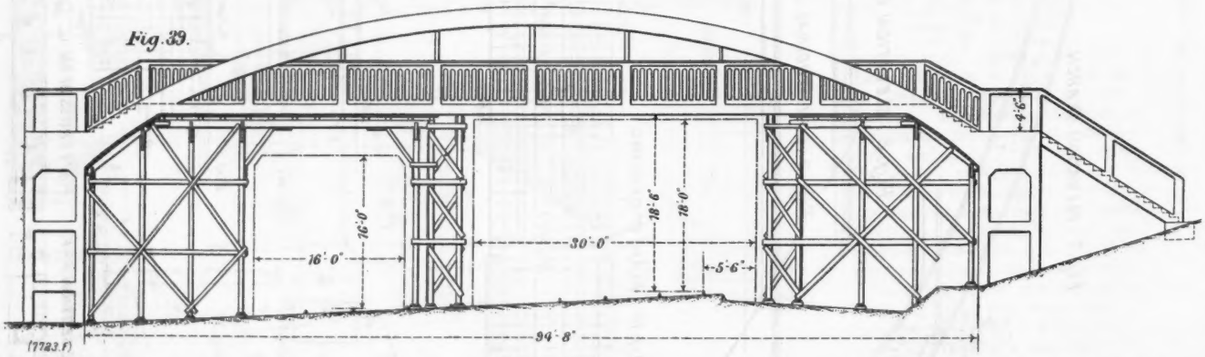
The reinforcing bars of the ribs run out into and are anchored in panel walls at the top of the towers as shown in Fig. 7. The decking is for a length of 94 ft. suspended from the arch ribs. Balustrading is provided on each side of the deck, divided up into eight sections. Between these sections is placed a pillar, 12 in. by 5 in. in section, and in the five cases in which the arch rises above the coping these are continued upwards to the rib in the form of 4 in. by 4 in. verticals. Reinforcing bars, $\frac{1}{2}$ in. in diameter and four in number, in each case are carried up these pillars and verticals, the ends being bent and anchored in the underside of the horizontal chord main beams, and in the upper side of the arch ribs. These bars are shown in Fig. 7.

The horizontal chord extending across the span of each arch is a beam 11 in. deep and 8 in. wide, as shown in Figs. 19 and 20. At intervals corresponding with the positions of the suspension members extending to the arch, cross beams extend between the main longitudinals. These are shown in Figs. 12, 14, 23, &c. In general the reinforcement of the main beams consists of three bars above and six below, or *vice versa*. Where there are three bars they consist of two of 1 in. diameter with one of $\frac{3}{8}$ in. between them. Where six are placed the additional bars are $\frac{3}{4}$ in. diameter. The latter run close to the upper bars near the suspension points and near the bottom of the beam in the middle of the spaces between these points. The ties are again 10 in. apart. Moulded into the upper side of the beams, as shown in Fig. 19, are a number of double triangular loop ties, through which the upper bars are threaded. A detail of one of these is given close to Fig. 11. These loops project up above the beams, and into the side mouldings and panelling, &c., of the balustrading, and reinforcing bars in the latter are threaded through them, thus providing an effective union of the two.

The cross beams are 9 in. deep by 6 in. wide, and are reinforced with two upper bars and two bottom bars (Fig. 14), the stirrups being also 10 in. apart. The decking is 3 in. thick at the sides and 3½ in. thick in the centre, the top 1 in. being a special quality of granite cement rendering. The decking is reinforced by means of longitudinals $\frac{1}{4}$ in. in diameter, and by transverse bars also of this size. The latter are placed 7 in., centre to centre, and run alternately right across the deck below the longitudinals, and partly below, with their ends above, the longitudinals.

Details of the towers are shown in Figs. 29 to 38, subjoined. As already explained, these serve to show the construction of both towers, which differ only in height, and in the fact that in the east tower the stairway leads straight on from the bridge, while on the west side it descends at right angles to the bridge. The towers measure 6 ft. 8 in. by 6 ft. 8 in. outside the columns, of which there are four, 12 in. square in section. The columns are reinforced with four vertical $\frac{3}{4}$ in. bars. At intervals horizontal braces are provided, 12 in. deep by 8 in. wide, reinforced with four $\frac{7}{8}$ in. bars, which at the ends of the beams are bent through 90 degs. and embedded in the columns. At the top the taller tower is walled in on three sides. On two of these, in line with the arch, the walls are 12 in. thick and 4 ft. deep; on the third side the wall is merely an ornamental panel 4 in. thick. In the smaller (east side) tower the space between the columns is only filled in at the sides forming a continuation of the





arch ribs. Diagonal ¾ in. bars run from these filling panels into the legs of the towers, as shown in Figs. 29 and 30.

Each tower stands on a footing measuring 12 ft. by 12 ft. and 8 in. thick, stiffened by ribs or inverted beams extending right across the slab in the lines of the columns, two being parallel with the line of the bridge and two at right angles. Of the latter the one on the arch side of the tower is 1 ft. 11 in. deep (Fig. 35), the other being (Fig. 34) 1 ft. 5 in. deep. The two in line with the bridge (Fig. 32) have a depth of 1 ft. 5 in. near the outside columns, increased to 2 ft. 6 in. at the inside columns. The thickness in all cases is 12 in. The reinforcement of the beams and slabs varies from ⅜ in. to ⅞ in. bars with the position, the lighter being employed on the parts of the slabs outside the outer columns, We have already referred briefly to the stairways, which do not call for further comment. The foundation slab on the east side was overlaid with a block of lean concrete 4 ft. thick.

At the commencement of this description it was stated that this piece of work was interesting because of the method employed in erection. The railway curves at this particular point, and in order not to interfere with the sighting of signals it was essential that a 30 ft. gap should be left in any false work in order to avoid obstruction to view. The siding line also had to have 16 ft. clearance allowed. Fig. 39 shows the false work which it was possible to erect under these conditions, this false work being seen also on Fig. 40, page 526. In order to span the large gap without interfering with traffic or blocking the line, it was decided to pre-cast a 35 ft. section of the decking and main beams and lift it into position. The section treated in this way is illustrated in Figs. 15 to 17, page 515, while its position in the bridge is shown in Figs. 9 and 10. The projecting ends of the reinforcing rods of this pre-cast section are clearly shown in Figs. 15, 16 and 17. The rods were bent upwards temporarily to facilitate lifting into position, the manner in which they were arranged being indicated in Figs. 18 and 26. The pre-cast section was made on a piece of ground adjoining the site on November 18, 1921. A timber cradle was made for it, in order to ensure it being slung safely when lifted.

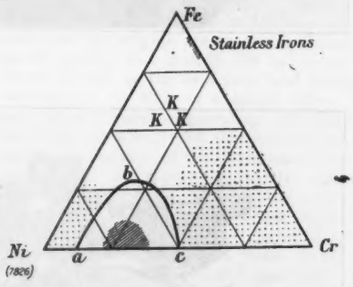
Exactly a month after pouring the concrete the section was lifted into position on temporary false work on both sides of the main line. For this operation the Great Central Railway Company's travelling breakdown crane was employed, and the whole work accomplished in a very short interval between traffic on a Sunday morning. The operation is well illustrated in Figs. 41 to 43, page 526, in which Fig. 41 shows the pre-cast member in its cradle, on the point of being slung by the crane. Fig. 42 shows the load lifted and the crane slewing towards the bridge, while Fig. 43 shows the section hoisted into position. When lowered on to its temporary supports two light trusses, which can be seen in Fig. 40, were constructed over this length, to assist it in carrying the load imposed upon it by the construction of the arch ribs, &c., above. The weight of the pre-cast member was 6½ tons. The bridge was completed about two months after the placing of the pre-cast section, the line not being occupied during the whole construction, except for the short space of time referred to above.

It may be stated that this contract was secured in the face of competitive tenders for steel structures, while the methods adopted in erection caused practically no greater interference with the main line traffic than would result from launching a steel girder bridge. With the exception of a foreman, and a few skilled men, all the labour employed was obtained locally, and the bulk of the material was similarly procured.

ALLOYS RESISTANT TO CORROSION.

THE Sheffield Section of the Faraday Society, joined by the section of the Institute of Metals and by the Manchester Metallurgical Society, discussed on the 13th inst. in the Department of Applied Science of the University, papers on "Alloys Resistant to Corrosion," under the presidency of Professor Cecil H. Desch, D.Sc., F.R.S. In opening the proceedings Dr. Desch remarked that the explanations so far suggested for corrosion effects were not satisfactory, and that particular attention should be paid to mechanical and physical conditions.

In the first paper read, on the "Mechanism of the so-called Dry Corrosion of Metals," Mr. Ulick R. Evans, of Cambridge, dealt with the "apparently dry type" of corrosion. He distinguished the "wet" corrosion, in which the metal is completely immersed, the more rapid "wet and dry" corrosion by periodical wetting, and the "apparently dry" corrosion either by air in the absence of moisture, or by the invisible film of moisture on the metal. As Mr. Evans also considered the influence of the presence of volatile electrolytes, of contact with dissimilar metals and of humidity (dew films), his qualification of the adjective "dry" is very essential. He is exposing thin sheets of metals, pure or commercial products, coins, bolts, &c., mostly roughened with emery paper, in glass desiccators for periods of two weeks or more, in winter and summer, to the action of various chemicals; in the contact tests strips of three metals were joined, either to form triangles, by the aid of iron bolts on which the triangle rested as on a tripod, or by making two sets of four strips cross like the warp and woof of a fabric. Mr. Evans found that the apparently-dry metals did not corrode over sulphuric acid which would, of course, adsorb any moisture present. Over water there was mostly slow corrosion, which



was hastened by volatile electrolytes, sulphur dioxide proving most dangerous to iron and nickel, ammonia to copper and its alloys, and hydrochloric acid to zinc and aluminium. Most of the manifold experiments confirmed and extended previous observations; but—contrary to expectation—ammonia did not rust iron. While some investigators believe in the possibility of direct oxidation in the dry, Mr. Evans suggested that electro-chemical action would always come into play in the adherent, frequently invisible, film of moisture, and that volatile electrolytes accelerate corrosion by increasing the conductivity of the film or by causing further adsorption of moisture; when the oxidation products were deliquescent, the corrosion was very rapid. We might perhaps say in other words, that the formation of an insoluble oxide film arrests progressive corrosion, whilst soluble and hygroscopic compounds favour further corrosion.

Dr. W. H. Hatfield, following with a paper on "The Corrosion of Industrial Metals," gave an account of investigations, conducted at the Brown-Firth Research Laboratories, on various irons and steels, comprising stainless F.G. steel and tantiron, nichrome, Monel metal, aluminium, brass and several bronzes (phosphor, manganese, aluminium and tin), which were also tested mechanically and metallographically. The results may be summarised in the statement that there are no laws at present available which can effectively guide the investigator of these problems. Electric potential tests in particular are difficult to interpret. With rapid solution and corrosion the potential is generally highly negative, with highly positive potentials there is very little corrosion; otherwise the magnitude of the potential affords little guidance. Speaking generally the observations point to the importance of protective surface films.

The work of the author of the next paper, on "The Resistance to Corrosion of Stainless Iron and Steel," Mr. J. H. G. Monypenny, of the Brown-Baily Steel Works Research Laboratories, Sheffield, has, like that of Dr. Hatfield, been noticed by us on other occasions. In his contribution, Mr. Monypenny dealt first with the effects of thermal treatment. Quenching from 900 deg. to 950 deg. C. leaves a normal steel insoluble in water and certain media; higher temperatures increase the risk of cracking during hardening; tempering to 500 deg. and 600 deg. C. diminishes both the hardness and the resistance to corrosion, and the influences of varying proportions of carbon and chromium vary much with the corrosive agent. Stainless steel rarely contains more than 0·3 per cent. of carbon, stainless iron 0·1 per cent. and less; other conditions being equal, less carbon and more chromium counteract corrosion, but commercial considerations and machining properties favour a chromium percentage between 11 and 14. Small percentages (1 or 2) of nickel and silicon have little effect on corrosion. Stainless steels resist water (including sea water) and superheated steam, also in the presence of lubricants. The attack by vinegar may be greater than that by pure acetic acid, of which vinegars contain 4 per cent. or 5 per cent., because vinegars may be contaminated with mineral acids; citric acid attacks stainless steel like acetic acid, whilst fruit juices are less corrosive. The protection afforded by oxidation, produced by heating for days to 750 deg. C. and more, was found much less effective for mild steel, nichrome and high-speed steels than for stainless steels.

We regret to have to deal briefly with Mr. J. Ferdinand Kayser's studies of "Heat and Acid-Resisting Nickel-Chrome-Iron Alloys," which were conducted in the laboratories of Messrs. Sybry, Searls and Co., and of the Spartan Steel Company. Mr. Kayser pointed out that, in the annexed triangular diagram, most of the heat and acid-resisting alloys would fall within the area *a b c*, and the best of them within the shaded zones. The dotted area did not contain useful alloys; the K marked non-corrosive alloys to which more attention had been paid in Germany than over here. The *a b c* alloys were all similar in character; they might contain from 10 per cent. to 30 per cent. of chromium, and as much iron as the stress to be withstood would allow. Wire for winding heating stoves might contain 27 per cent. of iron; for large case-hardening boxes the percentage limits were 12 Fe and 20 Cr. The carbon percentage depended largely upon the process of manufacture; a low carbon content mostly indicated that low-carbon ferro-chromium had been used. Nickel and aluminium formed a compound NiAl, of a high melting-point (above 1,700 deg. C., nickel 1,340 deg. C.) under evolution of great heat, and when aluminium was added to a fused bath of NiCr, this compound fell out in needle crystals, sharp at both ends. That addition of aluminium made the alloys very hard, and the hardness was not affected by heat (Kuehnrich).

The following table of typical alloys does not mention some minor constituents, which we shall add in each case:—

	C.	M.	Si.	Cr.	Ni.	Al.	Cu.	Fe.
1	0·94	1·1	1·9	21·0	68·0	—	—	7·0
2	0·27	0·06	3·9	29·0	62·4	—	—	4·9
3	0·09	0·02	0·46	15·6	81·2	0·42	—	0·8
4	0·5	0·79	0·8	13·8	57·5	—	—	27·3
5	—	0·08	1·04	21·07	60·7	1·09	6·42	0·76
6	1·13	2·2	0·63	15·5	64·9	—	—	15·8
7	0·68	1·4	0·22	10·8	62·7	—	0·108	24·07
8	1·37	1·9	0·49	8·5	40·0	—	5·5	42·0
9	0·6	1·88	1·17	13·2	59·9	—	—	23·2

Of these alloys, No. 1 was most generally useful, though not economical; No. 2 (and also 1) contained too much silicon, but was a good alloy; No. 3 (which further contained 1·56 per cent. of cobalt and 0·42 aluminium, possibly as impurities), was suitable for wire, but expensive; No. 4 was rather a poor alloy; No. 5 (which further contained 1·09 Al, 6·42 Cu, 2·13 tungsten, 4·7 molybdenum) was especially developed by Parr for the manufacture of Mahler bombs, and the additions were made to obtain greater density. No. 8 was also a rather poor cheap alloy; copper was not desirable in these alloys, and the high copper content was bad. No. 9 was cheaper than No. 1, but would not stand severe conditions so well. All these alloys, chiefly intended for use at high temperatures, became more ductile by heat treatment; as to their mechanical

properties and scaling, Mr. Kayser referred to the paper which Mr. J. H. S. Dickenson last year brought before the Iron and Steel Institute (ENGINEERING, vol. xciv, pages 326 and 378). In his comparative corrosion tests Mr. Kayser found his ternary alloys less liable to attack than stainless steels. But he did not confirm the often-claimed immunity of nickel-chromium from attacks by sulphur (SO_2 or H_2S) in furnace gases. Exposing these alloys in electric silica furnaces to coal gas and producer gas, steam, carbon dioxide, oxygen and ammonia, singly or mixed, at temperatures up to 1,150 deg. C., he observed that all the compounds within the *a b c* area behaved well, but that they turned scaly in the presence of the sulphurous gases mentioned. The brittle surface scales looked as if they had fused; they contained up to 12 per cent. of sulphur, and the sulphide Ni_2S (melting-point 644 deg. C.) seemed to have been formed.

Mr. John Arnott's paper on "Monel Metal" we printed on page 495 of last week's issue. He did not mention the composition of this alloy. It contains nickel and copper in the proportions of about 68 : 30, and in addition about 1·5 per cent. of iron. The alloy (density 8·87, melting-point 1,350 deg. C. about) is made directly from a matte by the International Nickel Company; the Report of the Royal Ontario Nickel Commission, Toronto, 1917, to which we may refer, gives also strength and corrosion figures; otherwise little has been published on the corrosion of Monel metal.

Sheffield had already discussed these corrosion problems last December (see ENGINEERING, December 15, 1922, page 747), when the Sheffield Association of Metallurgists and Metallurgical Chemists had assembled, and the new discussion testified to their industrial and commercial importance. Mr. R. Orme's notes on nickel steels will be found abstracted on another page. Reference was also made to metals not mentioned in the papers to which we have referred. Mr. Harold Turner was able to announce that very satisfactory progress had been made in the production of stainless silver; the difficulty in that case was that the hall-mark and the legal silver percentage of 92·5 left little margin for the introduction of anti-corrosive constituents.

SINGLE HELICAL DOUBLE-REDUCTION GEARING.

WE give illustrations on this page of a double-reduction gear supplied by Messrs. Brown, Boveri and Co., Baden, Switzerland, to a cargo steamer developing 3,000 shaft horse-power. The speed of the turbine pinion is 3,000 r.p.m., that of the intermediate shaft 600 r.p.m., whilst the propeller shaft makes 75 r.p.m. A notable point about the gear is the adoption of single instead of double helical wheels. The main reason for the general use of the latter type has no doubt been a desire to eliminate end thrust, but nowadays thrust bearings are no longer sources of anxiety. In the present case the end thrust on the first motion pinion is taken up at the turbine, and that on the main wheel is in such a direction as to relieve the load on the propeller shaft thrust block, whilst in the case of the intermediate shaft, the end thrust is practically eliminated by adopting a different helical angle for the wheel and for the second motion pinion. In this way the end thrust due to the pinion teeth can be perfectly balanced by the end thrust on the wheel teeth. The necessary and sufficient condition is that the tangents of the helix angles shall be in the inverse ratio of the diameter of the wheel to that of the pinion. Theoretically the end balance thus obtained is perfect, but thrust bearings are provided to take up any slight residual axial force that may arise from accident or imperfections in the teeth. It may be added that the wheels on the intermediate shafts are elastically mounted on their hubs. The makers state that with this arrangement they have secured very silent running and highly satisfactory service.

The general arrangement of the gear will be best understood by reference to Fig. 1. The high pressure and low-pressure turbines drive separate shafts, and each pinion on these shafts is in gear with two wheels on intermediate shafts, so that bending strains on the pinion shaft are largely eliminated and it is subjected accordingly to little but pure torque. The arrangement is shown still more clearly in Fig. 2. As stated, the wheels on the intermediate shaft are elastically mounted, thus ensuring that each transmits its due share of the total load with a consequent absence of bending strains on the pinion shaft.

SINGLE HELICAL DOUBLE-REDUCTION GEARING.

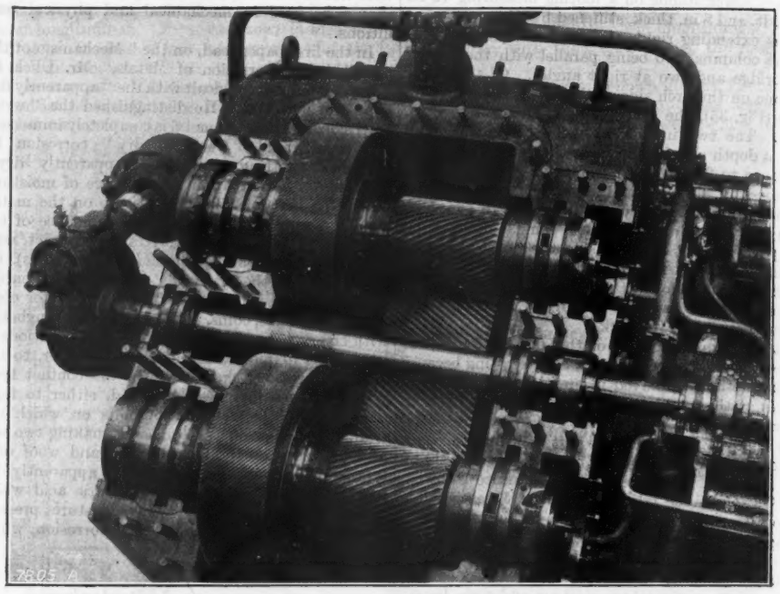


FIG. 1.

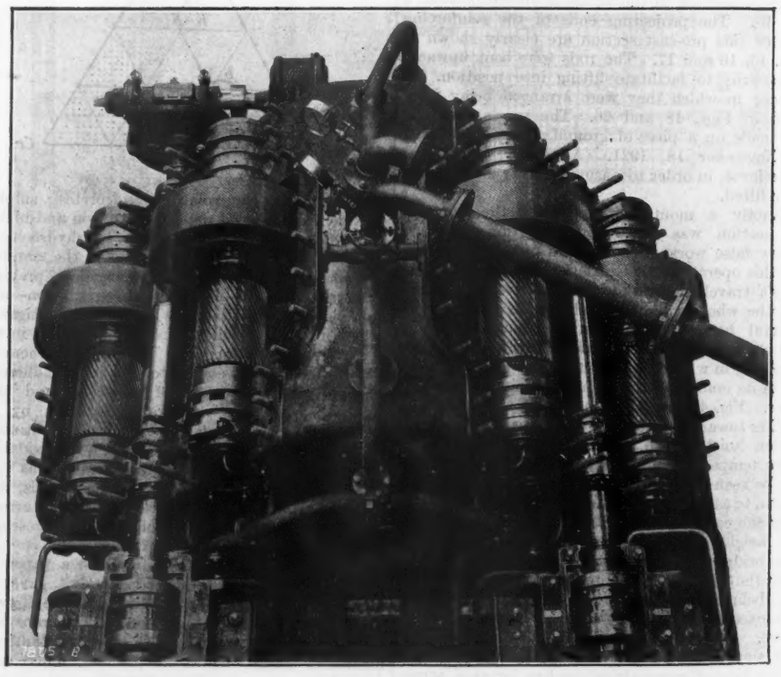


FIG. 2.

CONDENSER TUBE CLEANING.—To reduce the time taken in cleaning foreign matter from condenser tubes, Mr. D. B. Brearley, of the Barrow Corporation Electricity Department, designed a high-pressure water-jet apparatus which is manufactured by Messrs. W. Crockatt and Sons, Limited, of 64, Darnley-street, Glasgow. The shaped nozzle is formed within the pistol barrel and the water is directed through it, or to waste, by valves which are operated by means of a spring-held lever. The waste valve is also spring controlled, so that it may act as a relief valve if any tube is completely obstructed.

DANGER OF EXPLOSION IN BENZINE PIPES.—The danger from electric sparks which may arise when benzine is passed through metallic pipes, were alluded to during the discussion of Mr. Gibson's paper on "Oil Pumping," to which we refered recently on page 241. Earthing was recommended to avoid this danger, but earthing is not always a safeguard. Experimenting on this problem, Bruno Müller points out in the *Chemike Zeitung*, that the chief danger lies in the benzine itself. The benzine and benzine vapours become negatively charged, and sparks may cross at points where the vapours issue from the pipe; the earthing of the system would not prevent that. High potentials may be set up, especially when the pipes and tank are not full, so that there is also air-friction. Accidents are found to be more frequent in cold weather than in summer. The reason suggested for this is that probably the benzine evaporation is accelerated by heat; in warm places the benzine vapour will be saturated and the benzine-air mixture be too rich in benzine and too poor in oxygen, to be explosive. On cold days the mixtures is more likely to be explosive. In order to reduce the risks, benzine tanks, Müller proposes, should be charged with inert gases, as is done by Martini and Heinecke.

THE INSTITUTION OF MECHANICAL ENGINEERS.

An ordinary general meeting of the Institution of Mechanical Engineers was held at Storey's Gate, Westminster, on Friday last, the 20th inst., the chair being occupied by the president, Sir John Dewrance.

Hardness Tests Research.

Following the transaction of the usual formal business, the two papers set down for reading and discussion were proceeded with. The first paper, on "Static Indentation Tests," was read in abstract by the author, Mr. R. G. C. Batson, of the National Physical Laboratory. The second paper, was "On the Relation between Width of Scratch and Load on Diamond in the Scratch Hardness Test," the author being Mr. G. A. Hankins, also of the National Physical Laboratory. Mr. Hankins also read this paper in abstract. Both the above papers are printed in full in another part of this issue.

Dr. W. Cawthorne Unwin opened the discussion, remarking that the papers were so complete that they left little room for discussion. Mr. Batson dealt with the indentation of the load, and established that when the Brinell hardness number was constant for different sizes of balls the load was proportional to the square of the diameter of the ball, as shown in Table I of the paper. The results were extraordinarily consistent, and he thought Mr. Batson had proved the law in the cases examined. He had, however, tested the case only for one material, and it was necessary to apply the test to a different material; this verification was desirable. It would simplify matters to use, as suggested, the load divided by the projected area of indentation, instead of load divided by the more complex function used by Brinell, and it would be possible to pass from one hardness number to another, because the two would be related by a factor easily calculated from $\frac{W}{D}$. He thought that this plan should be adopted for proportioning load to the square of diameter of the ball. Table II in the paper showed two series of loads, one a 3,000-kg. load on a 10-mm. ball and the other a 500-kg. load on a 10-mm. ball. To bring the results into correspondence the two sizes of balls should be standardised; say, a 10-mm. ball for 3,000-kg. load and a 4-mm. ball for about 500-kg. load.

Fig. 4 in Mr. Hankin's paper gave tests using 10-mm. ball and measuring depth of impression, while Fig. 5 dealt with the same thing, but measured the diameter of the impression. This latter figure showed strongly marked curves, but Fig. 4 showed straight lines, almost exactly parallel to the axis. It would seem that in the ball test it would be better to use the depth measurement than the diameter measurements. The uniformity of result when the depth was measured was quite striking.

Fig. 6 gave cone results when measurement was made of the depth and, in Fig. 7, measurement was made of diameter. In the cone test, depth measurement gave curves, while the diameter measurements gave the results which were very nearly independent of the load, so that in the case of the cone test it would appear desirable to measure the diameter. He thought it probable that in the depth measurement the ridge should not be taken into account. It was of great importance that, to some extent, the indentation test should be rationalised. In 1900 Martell made a most interesting research in indentation tests, which appeared to indicate two things: Firstly, that the work, expended in indenting a body was directly proportional to the volume of the indentation. He (Dr. Unwin) had obtained a similar result fifty years ago when attempting to determine the penetrating power of shot on armour plate. He had measured the indentations and compared the volume of indentation with the work done by the shot. That law was confirmed by Mr. Batson's experiments. According to Martell, the volume of indentation was independent of the form of the indenting tool. Martell's second law was that the indenting pressure at each moment was proportional to the projected area of the indentation. He did not consider that law to be so satisfactorily decided. Out of the two laws, however, it seemed possible that some rationalising of the two hardness tests might be reached. It was not generally realised how empirical the indentation test was. If the effect of the ridge were included one thing was obtained; another, if it were excluded; one result followed the use of the ball, another the use of the cone. Again, there was another result from employing the impact test, and yet another by the employment of the Shore test. Until it was clearly understood what happened in indentation, rationalising of ideas on the subject would be impracticable.

Mr. E. G. Herbert next exhibited a number of lantern slides by means of which he described his new pendulum hardness tester. Instruments were also exhibited at the meeting. This testing appliance consists of a pendulum of inverted U-shape, carrying at the centre of the loop a chuck holding a ruby or hard steel ball, 1 mm. in diameter. The pendulum limbs are furnished with six movable weights, by means of which the pendulum can be adjusted to a vertical position when placed with the ball resting on the hard surface to be tested. Another weight is provided in the middle of the U, above the ball. This can be raised or lowered to adjust the height of the centre of gravity with regard to the centre of the ball. A scale and bubble are provided and one of the tests consists in tilting the pendulum until the bubble stands at zero and then letting the instrument swing until it comes to rest, when the position of the bubble on the scale is read off. A second test consists in taking the time in seconds for 10 swings of the pendulum by means of a stop watch, the oscillation being set up by touching the instrument very lightly with a feather. In the standard test the weights are so arranged that the centre of gravity is 1 mm. (0·039 in.) below the centre of the ball, giving on a very hard substance 10 seconds for the time of a single swing. Mr. Herbert showed curves illustrating the character of the results obtained with this instrument, and also micro-photographs of the impressions made by the rolling ball. He considered that the time test was an indentation test, whereas the scale test in which the movement of oscillation taken was measured, was a working or flow test. The time test will give 3 seconds for lead, brass 10–12, soft steel 20–40, hard steel 50–85, and glass 100. The swing is usually through 1 deg. or 2 deg. only.

With hard, but easily fractured material, such as cast-iron, a relatively high indentation is obtained and a scale or working number not much higher; the ratio between the two is perhaps 1·2 or 1·3. With high-speed steel, a lower indentation figure and lower Brinell test, are obtained, but a much higher working test figure, and the ratio, instead of being 1·2 or 1·3 goes up to 1·9. Manganese steel and rustless iron, both extremely refractory in hardening, also give an abnormally high ratio between the scale reading and the time reading; there is thus much evidence to support the view that some indication, if not a measure, of the workability of the material will be given by the ratio of the scale hardness to the time hardness. Mr. Herbert had so far had to rely upon empirical formulæ, in attempting to find a relation between the two scales, and the best he had been able to work out at present suggested that the time hardness number squared, multiplied by 0·3, would give a fairly close connection, for unhardened materials. For hardened steels the formula ceased to apply. By an extraordinary coincidence the time hardness number multiplied by 10 gave the Brinell hardness exactly: 60 times : 600 Brinell.

Dr. T. E. Stanton pointed out that, the appliances actually described in the paper were not really testing machines, but formed part of experimental apparatus. It had struck him that the two tests mentioned by Mr. Herbert were in reverse order to that which Mr. Herbert suggested. The time scale, he thought, was really an abrasion test. After the instrument had settled down the motion would be purely relative; instead therefore of being a hardness test it was a wear or abrasion test. He would have expected the scale test to correspond with the Brinell test, because plastic deformation did exist in the scale test.

Dr. Harold Moore did not think that the empirical character of the hardness test should be regarded as condemning it. It was of great practical value. None of the indentation tests determined the fundamental property of the material. The results of the experiments described in the papers were of great value and interest. Meyer's law of comparison might be expressed thus: With balls of different sizes loads proportional to the squares of the ball diameters produced geometrically similar indentations in uniform material, and gave the same hardness number. Mr. Batson's further confirmation of the law, over a wide range of deformation, was valuable. The question was growing in importance because of the increasing use of small balls and correspondingly small loads in Brinell hardness tests. There were practical objections to Dr. Unwin's suggestion of standardising two sizes of ball and two loads, because the size of ball had to be adjusted to the thickness of the specimen; at all events on thin specimens a small ball must be used. At the Research Department at Woolwich balls of 1 mm. in diameter and even less had long been used for determining the hardness of thin specimens.

Mr. Batson's results were not so concordant as he would have expected from his own experience. The degree of accuracy obtainable in the Brinell test was exceedingly high. The difficulty in comparative tests was to secure uniform material, The Brinell hardness number of the mild steel used by Mr. Batson was just over 100, and it was difficult to get uniformity of hardness in such material within 2 per cent. The material used in the tests in Table II was harder (Brinell No. 140) and may have been more uniform. Mr. Batson had referred to his suggestion that the diameter of the test pieces should be at least 4·5 times the diameter of the impression. His actual recommendation was five times, but he would re-state the proposal as follows: The centre of the impression should not be less than 2½ times the diameter of the impression from the nearest edge. The Brinell system was introduced with the idea of correcting for the increasing hardness number with increasing load with the same diameter of the ball. It, however, failed seriously to do that; and no method of the kind could do it, because the materials differed in rate of hardening under cold work. With regard to the cone test soon after its introduction in 1907 it was investigated at Woolwich. The point of the cone, however hard the material, was never perfectly sharp. For that reason the depth of the impression was not really the desired figure; what was wanted was the virtual depth rather than the actual depth. He had found that an accurate way of determining virtual depth was by means of a ball-pointed spherometer seated in the impression. With moderately hard steel there was a distinct ridge at the edge of the indentation, with mild steel the rise of material at the edge was much less, while with copper the edge was depressed below the original level.

Professor Thomas Turner, referring generally to the problems due to the differing effect of work, remarked that it was obvious that the size of the rim was an indication of the amount of cold work put upon the specimen. If a sample were annealed and pressed a second time the ball would enter further; if annealed again, the ball would go to the full depth, usually, giving the correct hardness, which was something smaller than the observed hardness, because the latter was the natural hardness of the material plus the cold work put upon the metal immediately adjacent to the pressure. Theoretically there were many reasons for preferring the scratch test to the indentation test, but there were practical difficulties in its application. The original method of scratch test was introduced nearly one hundred years ago. About forty years ago the test was improved in a way which made it answer for the time, but its accuracy was only about 5 per cent., and, in applying it to hard steels, it failed. A succession of scratches were viewed according to a prescribed method of illuminating, but it became difficult to know which scratch should be observed. The study of scratches therefore became important, and five years ago he experimented with a piece of apparatus something like that employed by Mr. Hankins, with a fixed weight on a diamond. In his case the diamond was moved with a rack and pinion, the weight was applied vertically and the specimen exactly horizontal. The chief difficulty was that the point of the diamond seemed to dig into the material then jumping out and digging in

again. This was probably due to too rapid movement of the diamond; Mr. Hankins' diamond was moved slowly. His object had been to put into the hands of a workman an apparatus which would enable rounded and finished articles to be tested for hardness; that object was not obtained. He considered that it was essential to make a study of the character of the scratches before proceeding further. He thought it would not be possible always to work to one constant, some materials being so soft that even 10 grammes would suffice, and he therefore suggested three weights, say, 10, 50 and 100; which would give three definite scratches. The amount of material removed bore a definite relationship to the weight upon the diamond, and the values of the 10-gramme weight could therefore be readily converted into the 50-gramme or the 100-gramme. He hoped that Mr. Hankins—or someone else—would utilise the information in the paper and devise a practical apparatus, suitable for every scientific research department.

Professor H. D. Philpot said that he would have been glad if Mr. Batson had been able to make a definite statement as to the best law to use when working out hardness numbers. Judging from Fig. 1 it seemed that Mr. Batson was satisfied that the law derived from Meyer was a better rule than the Brinell rule, but he doubted whether this was really proved. As the ratio $\frac{d}{D}$ increased the curves rose, showing that the area which should be used in order to get a uniform value for the hardness number would be one which should increase with the ratio of $\frac{d}{D}$. So far as the results shown in the Table I were concerned, it would be found that the Brinell hardness number gave more constant results than the $\frac{P}{\frac{\pi}{4}d^2}$ formula. He had worked over the series of tests in Table I to obtain both the Brinell values and the values of $\frac{P}{\frac{\pi}{4}d^2}$, and in the five curves given, each curve having an approximately constant ratio of $\frac{d}{D}$, it would be found that the different values varied considerably by both rules, but taking the mean of each series, the following $\frac{P}{\frac{\pi}{4}d^2}$ values were obtained:—

93·34 as the mean of the first group of results.
103·5 as the mean of the next group.
111·8 as the mean of the next group.
116·4 as the mean of the next group.
120·6 as the mean of the fifth group.

The mean values for P divided by the spherical area—the Brinell rule—were:—

90·6 for the first group.
100·2 for the second group.
105·9 for the third group.
105·9 for the fourth group.
106·1 for the fifth group.

The last three were approximately of the same value, showing that the Brinell rule did give fairly uniform results for that part of the scale in which $\frac{d}{D}$ was comparatively large. Plotting the results in detail, he came to the conclusion that Mr. Batson's material was not properly described as uniform as regards hardness.

Professor B. R. Haigh thought that Mr. Batson's paper would increase confidence in the small ball test, and show how to get comparable results from small balls and large ones. Mr. Batson had set out to demonstrate the validity of the laws of similarity and that being his avowed object, it was particularly unfortunate that he should so early say that such a law might be derived from Meyer's investigations published in 1908. The law was much older, and was expressed in the 'seventies by Professor James Thomson, in very much clearer language than that used recently. Professor James Thomson enunciated the law in a paper published in the Journal of the Institution of Engineers and Shipbuilders in Scotland. To that law little had been added, except perhaps by Osborne Reynolds and Lord Rayleigh in connection with the influence of viscosity. A previous speaker had mentioned that the Brinell impression was not always of the same shape, although the cup-shaped portion was the same. The latter was spherical, but the edge might be raised or depressed. In connection with this point Professor Haigh showed lantern slides representing comparable images of indentations formed by the prism hardness method, in which two prisms of exactly the same material were made to indent one another. The first slide showed a piece of cold-drawn hard copper with two indentations. He wished to direct attention to the spreading of the material round about the indentation with this material. A second slide showed the same material annealed. The shape was now entirely different, the material at the edges being depressed. Hardness was therefore not merely a numerical quantity, but different in kind as well as magnitude.

Mr. R. T. Rolfe said the engineer required a test giving the same hardness number even when he had to use different loads; for various reasons, it was impossible always to use the same load. In the Brinell test the variation of the hardness figure for different loads was a very unsatisfactory feature. To overcome the difficulty, he had found it necessary to plot a series of curves for different materials, so that it was possible, when departing from the usual load, to apply the necessary correction factor. Of course this method of applying a correction was troublesome, but the investigator was no better off if he used any of the empirical formulæ advanced to get over the question of variation in load. Professor le Chatelier had proposed that this variation might be overcome by adopting the formula

$$H = \frac{P_1}{A_1} \times \sqrt[5]{\frac{D_1}{10}} \times \frac{20{,}000}{17{,}000 + P_1},$$

where P_1 was the load in kilogrammes, D_1 the diameter of the ball in millimetres, and A_1 the area in square millimetres. That formula, however, did not give a constant figure; it did not correct for the variation of load, and was, in fact, no better than the figure given by the usual Brinell formula. He wished to draw attention to the series of curves shown in Fig. 4 of the paper, which demonstrated that, by taking the true depth of the indentations, an absolutely uniform hardness figure was obtained, whatever the load. He thought the most important deduction from the paper was that the ball test, if the ridge effect could be disregarded, gave more consistent results than the cone test. This matter was of importance in the interests of standardisation.

Mr. Batson confined his reply to one point, viz., the uniformity of the bar under test. Before carrying out the series of tests, a series of standard Brinell tests had been made right along the bar at intervals of about 1½ in. These tests were found to be very uniform in value.

Mr. Hankins also very briefly replied to the discussion, pointing out that the actual apparatus adopted in his work was not important as regards design. The conclusion to be drawn from the work was concerned with the effect of the actual shape of the diamond on the scratch made.

The President then announced that at an informal meeting on Friday, April 27, at 7 o'clock p.m., further discussion would take place on "Light Alloys in Place of Iron and Steel," introduced on February 2 by Mr. A. E. L. Chorlton, Member of Council. An outline programme and full particulars of the summer meeting in June would be issued to members in the June Journal of the Institution.

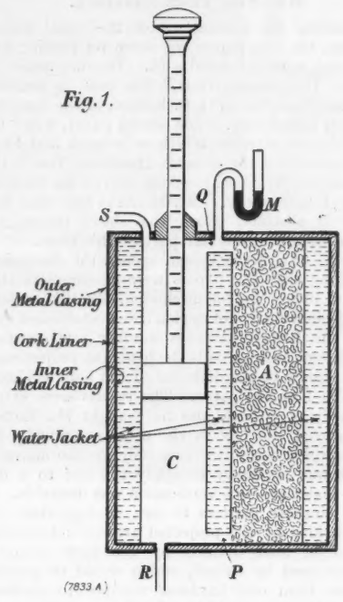
THE ROYAL TECHNICAL COLLEGE, GLASGOW.—At a meeting of the Governors of this college, held on the 17th inst., Dr. Stanley Parker Smith was unanimously appointed Professor of Electrical Engineering in succession to Professor Magnus Maclean, who is about to retire after occupying the chair for twenty-four years.

GERMAN GUN STEELS.—The Research Department, Woolwich, has issued R. D. Report, No. 57, which gives complete data on the chemical composition and physical tests of the steels of a number of captured German guns. The report also contains several micro-photographs. It states that in the case of the larger guns examined, the quality of the steel fell off during 1917–18, but adds that no marked deterioration was observed in the smaller ones. The mechanical tests showed that the average for each calibre was very near to the general average, but low elongation was observed more frequently in the larger forgings of 1917–18, this being due, according to the report, to the large amount of inclusions (chiefly sulphide) present in these forgings. The evidence of the researches recorded in the report points to a more hurried manufacture in certain instances as the war progressed.

THE ECONOMETER CO_2 TESTER.

A NEW and very simple type of portable apparatus for testing the amount of CO_2 in flue gases has been developed by Messrs. Kelvin, Bottomley and Baird, Limited, of 18, Cambridge-street, Glasgow. The instrument, which is normally contained in a cylindrical leather case, with a handle for carrying, is only 3¼ in. diameter by 10¼ in. long, and weighs only 4½ lb. It

Fig. 1.



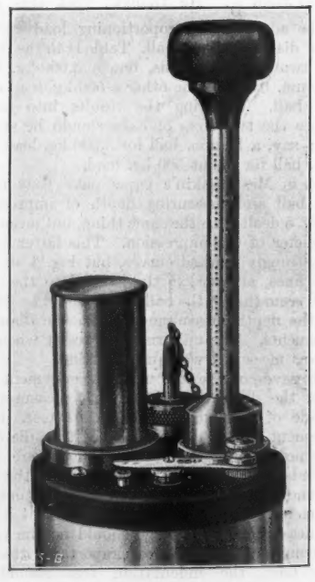


FIG. 2.

contains no delicate glass parts and does not make use of liquid absorbents, so that it requires no special care in use. Its accuracy, however, is such that, in the hands of an ordinary careful observer, the measurements of the CO_2 content of flue gas are claimed to be reliable within one-quarter of 1 per cent.

The case of the instrument is of metal, lined with cork, and a sealed water jacket further protects the working parts from changes of temperature due to external conditions while tests are being made. The determination of CO_2 is effected by noting the displacement of a piston which is required to restore the charge of flue gas to its original pressure after the CO_2 has been removed by combination with the caustic absorbent material. The principle upon which the instrument acts will be understood from the diagrammatic arrangement of the parts shown in Fig. 1 annexed. In

this illustration C represents the chamber into which a charge of flue gas is drawn by the piston, the gas entering by the pipe R after having passed through a drying chamber, not shown in the diagram. The connections, P, Q, R, S, can be opened and closed as required by means of a rotary valve, which also is not shown.

Before a test is taken, two or three successive charges of gas are drawn into the chamber and discharged to the atmosphere so as to ensure that the sampling tube is filled with undiluted flue gas. Assuming, now, that the piston is at the bottom of its stroke, the channels P and Q are closed, R is open to the flue gas by way of the drying chamber, and S is open to atmosphere. On withdrawing the piston to the top of its stroke a sample of gas is drawn into the cylinder. The reading of the manometer is then noted. Connections R and S are next closed and P and Q opened. The gas is next circulated once or twice forwards and backwards through the absorbing chamber by the motion of the piston, this operation being completed with the piston standing at the top of its stroke. The absorption of the CO_2 which this procedure has brought about entails a reduction of pressure in the gas, which is indicated by the manometer, this reduced pressure being, of course, proportional to the amount of CO_2 which was originally present. If now the piston rod is pushed down, the volume of the piston rod entering the space diminishes the room available for the gas and therefore increases its pressure. The piston rod is graduated, as shown in Fig. 2, which also shows the fittings at the top of the instrument. It is pushed in until the gas pressure is restored to its original value, as shown by the manometer, and from the graduations on the rod the percentage of CO_2 is directly read.

The piston road is made of non-corrosive material, and the manometer is a type of non-spillable liquid gauge. The design and construction of the whole instrument renders it suitable for ordinary boiler-room use. The absorbent material is caustic potash or soda, which can be purchased anywhere when renewal is necessary, and no special refilling cartridges are required. The instrument can be put away in any position and is always ready for use. Its handiness and portability render it specially suitable for snap-tests of flue gases.

INDUSTRIAL NOTES.

WE referred on page 277 *ante* to the case of a foundry worker at Rochester, who was fined 2*l.* by his union for having worked 45 minutes overtime in order to finish a casting. The case was decided at the High Court of Justice, King's Bench Division, last Monday, when Mr. Justice Coleridge delivered judgment in favour of the plaintiff, the foundry worker. In the course of his judgment, Mr. Justice Coleridge said he observed that trade union members addressed one another as "brother this" and "brother that"; it would be well, he thought, that they should drop that form of appellation until they had learnt what constituted the elements of brotherhood between man and man. He also stated that the defendants were, at common law, an illegal combination, because their main object was to restrain trade, and he further explained the legal position of trade unions.

The report for the current month issued by the United Society of Boilermakers and Iron and Steel Shipbuilders states that in August last, at the request of many branches that the society should leave the Engineering and Shipbuilding Trades Federation, the question was submitted to the members' vote and the result was, in favour of affiliation 2,922, against 2,248, majority in favour 674. The Executive at that time asked the members to vote in favour "in the hope that by an improvement in the constitution of the federation, the society, by remaining in the federation, would help in making it a more effective unit." The report adds that since that time the society's relations with the federation have been "less helpful and less in line with the clearly-expressed wishes of the society's members," and the society's Executive are now advising the members to vote against continued affiliation with the federation, "not because the society is against the principle of federation, but because the methods and constitution of the present federation are not working in practice, to the advantage of the society's members." The votes are to be taken at the June monthly meetings. This argument on the part of the society's Executive appears to us to be rather involved. The society is now, and may remain after the June voting, a member of the federation; such being the case, all decisions taken by the federation should be strictly adhered to by the society, this is only elementary fairplay. But the Boilermakers' Society, together with the joiners' and plumbers' unions have refused, as intimated in our former issues, to endorse the agreement arrived at by the federation on the questions of overtime and night-shift. Following this refusal, the shipbuilding employers posted on Monday notices stating that a lock-out will start on Monday next, the 30th inst., in shipbuilding and ship-repairing yards, unless the Engineering and Shipbuilding Trades' Federation intimates that the dissentient unions accept the agreement. Further, a strike of boilermakers at South Shields in violation of the agreement has also to cease.

A joint conference on the above points was held in London a few days ago. The men's federation Executive admitted that the agreement had been endorsed and signed on behalf of all the unions concerned, but they added that they had been unable to bring into line the outstanding societies. A resolution was submitted to the effect that as there had been a misunderstanding, the employers should suspend the operation of the agreement to enable further negotiations to take place. After further discussion, the Shipbuilding Employers' Federation handed to the men's federation Executive the following statement:—

"We have fully considered the resolution submitted, and the statement made on behalf of your federation. We have also considered the statement made on behalf of the boilermakers, joiners and plumbers' societies, members of your federation, with reference to accepting and honouring the agreement entered into between your federation and this federation on March 22 last. We deeply regret that your federation has been unable to secure the resumption of work by the members of the Boilermakers Society who are on strike in the Tyne district and the adherence to the agreement of the above named societies.

"We are of opinion that collective bargaining will be rendered impossible if an agreement constitutionally negotiated and concluded between two federations is allowed to be repudiated by constituent bodies of negotiating organisations.

"We feel compelled, therefore, to intimate that employment will not be available in federated shops on and after Monday, April 30, 1923, to members of these three societies—boilermakers, joiners, plumbers—unless your federation, prior to that date, intimates acceptance of agreement by those societies."

The Shipwrights form a fourth dissenting society, but they are said to be prepared to work "under protest."

At the time of going to press we are informed that the men's federation Executive have asked the employers' federation to postpone for a week the lock-out notices, so as to give time for a ballot of the boilermakers. It is added that the employers have agreed, provided that the agreement be observed in the meantime and the strikers return to work.

The Ministry of Labour state that although employment generally was still bad during March, the gradual improvement which had been in progress since the beginning of the year was maintained. At coal mines, in tin-plate and steel sheet manufacture, employment was good, and in the iron and steel, furnishing, leather and paper trades it was fair. In most of the other large industries it was still slack; but a further improvement was reported in the iron-mining, pig-iron, engineering, shipbuilding, building, wood-working and pottery industries. The percentage unemployed among members of trade unions from which returns are received was 12·3 at the end of March, as compared with 13·1 at the end of February, and with 16·3 at the end of March, 1922. The percentage unemployed among workpeople insured under the Unemployment Insurance Acts in Great Britain and Northern Ireland was 11·1 on March 26, as compared with 11·8 on February 26, and 14·4 at the end of March, 1922. The total number of workpeople registered at the Employment Exchanges as unemployed on March 26 in Great Britain and Northern Ireland was approximately 1,289,000, of whom 999,500 were men and 213,500 were women, the remainder being boys and girls. On February 26 the corresponding total was 1,376,000, of whom 1,073,000 were men and 218,000 were women.

In the industries for which statistics are collected by the Labour Department the changes in rates of wages reported as having taken effect in March resulted in an aggregate reduction of over 64,000*l.* in the weekly full-time wages of about 920,000 workpeople and in an increase of approximately 650*l.* in the weekly wages of over 16,000 workpeople. Over two-thirds of the total number of workpeople whose rates of wages were reduced were coal miners in Northumberland, Durham, Yorkshire and the East Midlands, Radstock and Scotland, who sustained reductions varying from under ½ per cent. on current rates in Radstock to nearly 3 per cent. in Yorkshire and the East Midlands. Among other bodies of workpeople whose wages were reduced in March were semi-skilled men and labourers in steel melting shops generally and in puddling forges and rolling mills in the North of England, ship repairers on the Mersey, shipbuilders at Belfast, electric cable makers and employees of local authorities in Lancashire, Cheshire and the West Midlands. Under the Trade Boards Acts there were reductions in the minimum rates fixed for various classes of workpeople in the stamped or pressed metal wares trade. The principal groups of workpeople whose wages were increased were iron ore miners in Cumberland and the Furness district and blast-furnace workers in West Cumberland and North Lancashire. During the first three months of 1923 the changes in rates of wages reported to the Department have resulted in a net reduction of over 160,000*l.* in the weekly full-time wages of nearly 1,600,000 workpeople, and in a net increase of about 19,500*l.* in the weekly wages of nearly 190,000 workpeople. In the corresponding three months of 1922 there was a net reduction of 1,210,000*l.* in the weekly wage rates of nearly 5,900,000 workpeople, and a net increase of 3,400*l.* in those of 20,000 workpeople.

On March 31 the average level of retail prices of all the commodities taken into account in the statistics prepared by the Ministry of Labour (including food, rent, clothing, fuel, light and miscellaneous items) was approximately 74 per cent. above that of July, 1914. The corresponding figure for March 1 was 76 per cent. The highest point reached was 176 per cent. above the pre-war level, in November, 1920, and the present figure is the lowest recorded since April, 1917.

The number of trade disputes, involving stoppages of work, reported to the Department as beginning in March, was 52. In addition, 28 disputes which began before March were still in progress at the beginning of the month. The total number of workpeople involved in all disputes in March was approximately 86,000, as compared with 40,000 in the previous month and 246,000 in March, 1922 (when disputes were in progress in the engineering and shipbuilding industries, involving over 200,000 workpeople). The estimated aggregate duration of all disputes during March was 834,000 working days, as compared with 337,000 days in February, 1923, and 2,980,000 days in March, 1922.

The lock-out in the Scottish jute industry mentioned on page 398 *ante* was settled and an agreement was arrived at last week at a conference of the employers and trade unions under the chairmanship of Sir David Shackleton, Chief Labour Adviser to the Ministry of Labour. All the mills and factories have restarted. The dispute lasted about a month; it involved 30,000 operatives and is said to have led to a loss of over 250,000*l.* in wages.

A lock-out in the pottery trade, which would have affected about 60,000 operatives, has been averted, the operatives having agreed to the employers' terms, involving a 10 per cent. reduction in wages all round.

The railway shopmen difficulty is still unsettled. On page 473 *ante* we stated one revised proposal made to the men by the railway companies. Another revised proposal is reported, according to which there would be a reduction in wages of 2*s.* from the first pay-day in May, then a further cut of 1*s.* in June and another cut of 1*s.* in July, the wages to be stabilised from July to January next. These conditions were considered at a meeting of the unions concerned held last Tuesday; the unions could not agree as to the course to adopt and the matter is at a deadlock. According to the latest news, this revised proposal made by the railway companies has been rejected by the craft unions concerned.

HOSE CLIPS.—Messrs. L. Robinson and Co., of London Chambers, Gillingham, Kent, have introduced a new type of clip which may be useful for many other purposes than the original one of clipping hoses to pipes. It consists of a mild steel ribbon with a simple housing for a screw riveted to the one end. A rack is cut on the ribbon at the other end. The ribbon is placed round the hose and the end passed into the housing under the screw. The square threads grip the rack as the screw is turned and the ribbon is tightened up on the hose.

BULGARIAN TRADE.—The factors which contribute to restrict British trade with Bulgaria are the depreciated currency, high costs of freights and custom dues. In spite of these conditions Britain stood third in 1921 in the table of countries of origin of imported goods, Italy and Germany occupying the first two places. Mr. Douglas MacKillop, in a report to the Department of Overseas Trade on the "Economic and Financial Conditions in Bulgaria," refers to the fact that little interest has been shown by British firms to the invitations to tender issued by the Government Departments. This, he suggests, is due to a mistaken view of the security of payment and to a dislike of the conditions stipulated by the different Ministries. No changes in conditions can be anticipated if competing firms of foreign nationality are prepared to accept them.

THE CAPROTTI LOCOMOTIVE VALVE GEAR.

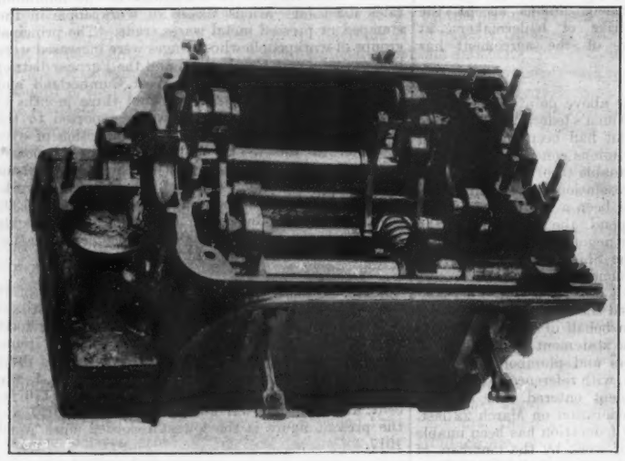


FIG. 7.

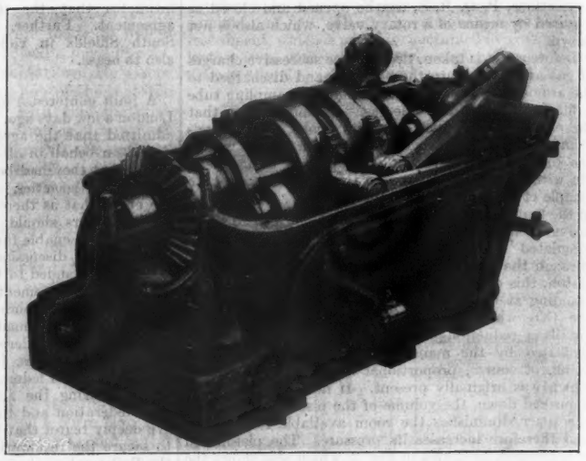


FIG. 8.

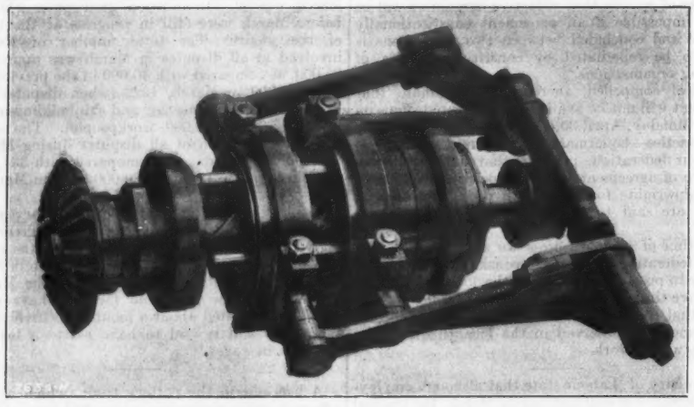


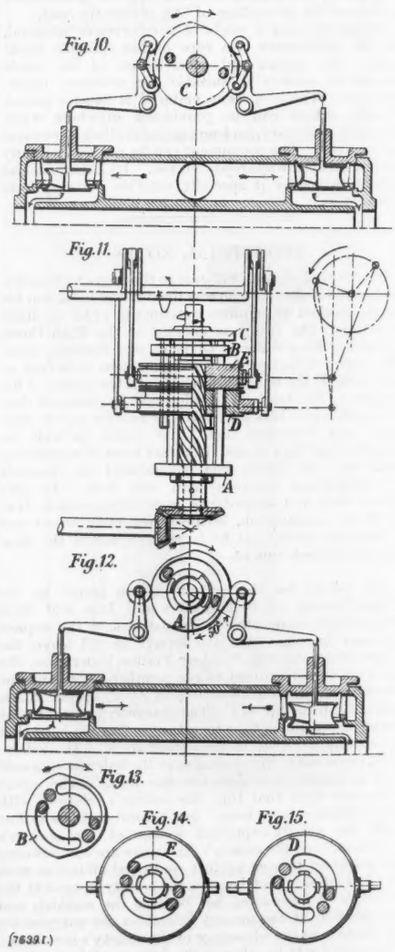
FIG. 9.

A VERY large number of attempts have been made in the course of the development of the steam locomotive to improve upon the ordinary link-motion and valve gear. This gear has the advantage of being simple and relatively cheap to make, and its function is fairly easily understood by the class of men who do the actual running of the locomotives. It has, however, various defects which have long been recognised, among these being the fact that the lead varies with different adjustments, while with short cut-offs the exhaust is closed so early that compression becomes excessive. In the very large locomotives used, for instance, in America, the gear becomes so heavy that the inertia effects are very serious and result in bad running qualities and trouble from heating. The numerous substitutes which have been brought forward at one time and another, as improvements, have for the most part been eliminated, with the exception of the Walschaert gear, which has the advantage of giving a constant lead and is capable of being designed on much lighter lines. There are others in use to some extent as, for instance, the Joy, and certain gears used to a limited degree in America. In the last twenty years, however, the use of the Walschaert gear which was once confined to the Continent, has spread to this country, and at the present day is preferred in American practice, where with the large engines a reduction in weight of 50 per cent. is found possible with this gear, as compared with the Stephenson link.

On the Italian State Railways a form of gear which is still lighter and eliminates inertia troubles altogether is being introduced. We refer to the Caprotti gear, which has now been fitted to a number of locomotives on these railways. This is quite a unique mechanism, not being worked by eccentrics or rods, but by a revolving bevel-driven shaft. It provides an exceptional range for the valve events. The gear is the invention of Mr. A. Caprotti, of Milan. We illustrate it in Figs. 1 to 6, Plate XXXIII, and Figs. 7 to 17, on this page and opposite. In the first engines fitted for trial the drive was taken from an outside return crank-pin on the centre line of the axle and therefore without throw, but the form of drive now adopted is off the axle between the frames, as shown in Figs. 1 and 16. The gear employs lift valves operated by cams, in order to secure quick opening and closing, large port openings and small clearance volume. The use of a revolving shaft eliminates all inertia effects on the mechanism arising from the double reversal of movement to each revolution of the driving wheel in the usual link gear.

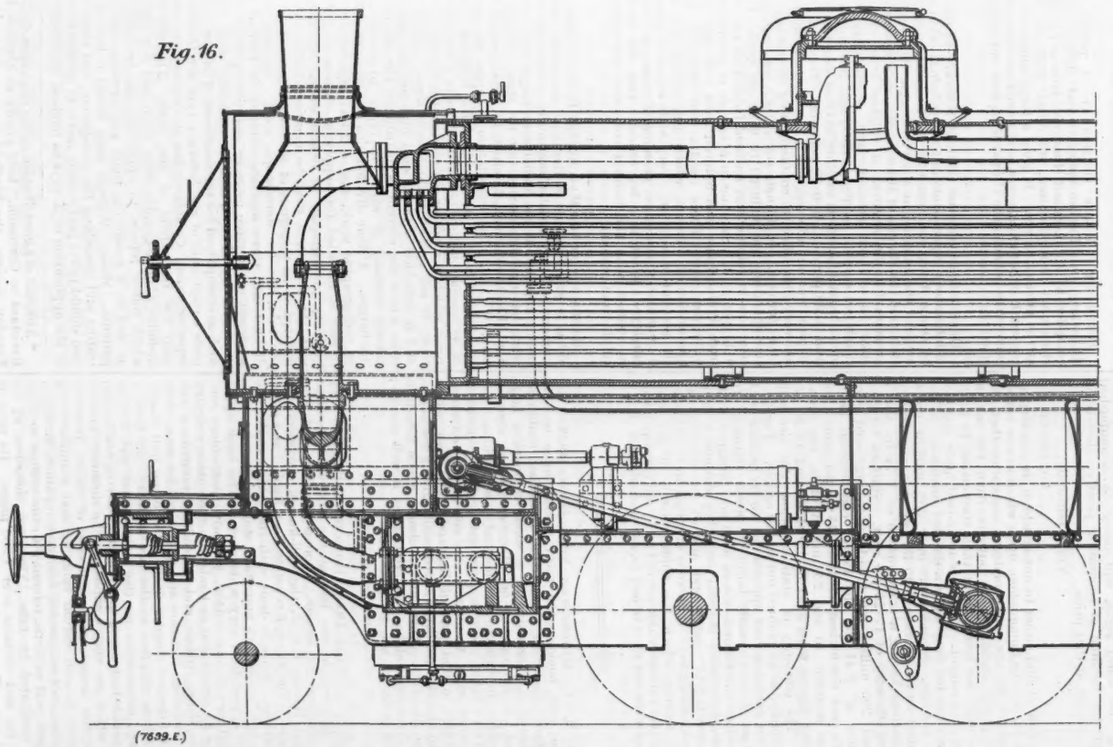
For each cylinder the Caprotti gear uses four valves operated by three cams. One cam operates both the exhaust valves, while a conjugate motion is transmitted from the other two cams together, to the two admission valves. The general arrangement of the drive off the axle is, as we have stated, shown in Figs. 1 and 16, the telescopic shaft driving a cross-shaft over the cylinder casting, either direct through bevels, as in Fig. 16, or through an intermediate shaft, as in Fig. 1, Plate XXXIII. The arrangement adopted, of course, depends upon the general design of the locomotive. The cross-shaft arrangement naturally varies also to some extent with the design of the engine, but the drawings, Figs. 3 to 6, Plate XXXIII, and the photographs reproduced in Figs. 7 to 9, above, will assist in the appreciation of the main principles of the gear. With outside cylinders, above the steam chest on each side of the engine, is placed a motion box, which is shown with its cover removed, in Figs. 7 and 8. This box contains the gear illustrated in Fig. 9, which works in an oil bath, the main member consisting of the cross-shaft driven by bevels from the transmission shaft and driving axle. The cams operating the valves are arranged on the cross-shaft and will be recognised in Figs. 5 and 6.

In order to make our description more lucid we have reproduced the diagrams, Figs. 10 to 15, which show the essentials of the gear. Fig. 11 is a plan in which the transmission shaft and bevels will be recognised, and A, B and C are the cams. The single cam A governs the movement of both exhaust valves. It will be noticed in Fig. 9, towards the left, and is shown in Fig. 5 and to the right of Fig. 3. The two other cams, B and C, work in combination, and provide a compound motion for the admission valves. These cams are best shown to the left of Figs. 3 and 4, and in Fig. 6. The diagram Fig. 12 shows the cam motion and transmission for the exhaust valve and the action of the crank lever on the valve spindle needs no further explanation for the moment. The mechanical details are well shown in Fig. 5. The compound motion for the admission



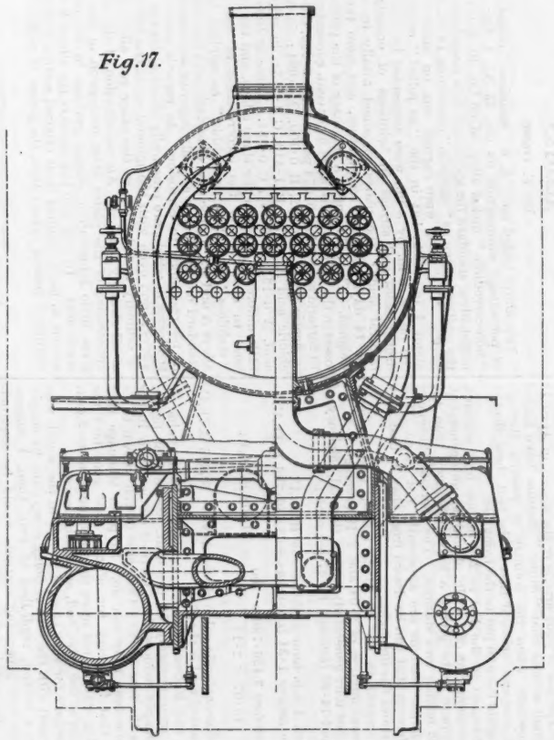
THE CAPROTTI LOCOMOTIVE VALVE GEAR: ITALIAN STATE RAILWAYS.

Fig. 16.



(7639.c.)

Fig. 17.



valves is very similar as regards mechanical detail, but the single cam roller of the exhaust side is replaced by two rollers on a pivoted beam, for the admission. One roller makes contact with each cam, so that the final movement transmitted to the valve is a combination of that of one roller on one cam with that of the second roller on the other cam.

The cams are driven by the cross-shaft, and the remainder of our description is concerned with the manner in which variations in this drive are obtained in order to suit different conditions of running and, of reversing. Dealing first with forward running only, the exhaust cam setting is normally fixed and is not varied. This cam is driven by the cross-shaft by means of a collar fixed to the shaft and carrying two dogs which engage in slots in the cam (Fig. 12). In the case of the admission valve the double cam arrangement makes it possible to alter both the lead and the cut-off. The admission can be more or less advanced by varying the angular position of the cam B, while the cut-off is varied by altering the angular position of the cam C. These two movements are secured in a way which provides for a small alteration of the position of B coupled with a large change in the position of C, or *vice versa*. This is obtained in the following manner: The cross-shaft is cut with a very quick pitch four-threaded screw, and carries, in addition to the cams, two wide-rimmed discs screwed internally in a corresponding manner. The drives of the cams B and C are derived from these discs D and E, the former driving the cam B and the latter the cam C. These drives are transmitted through two pairs of rods, and in order to allow of relative movement slots are provided in the discs. Figs. 13, 14 and 15, show the holes and slots for these rods. The rods transmitting the drive from D to B pass through slots in E, while the rods driving C from E project through slots in B and D. It will be obvious that any longitudinal movement of either disc D and E, along the cross-shaft will alter its angular position and the corresponding cam will thus be displaced angularly also. Variations of admission and cut-off may therefore be obtained by sliding the discs D and E along the threaded shaft, and this is accomplished by means of the double crank and connecting rods shown in the diagram Fig. 11, and the view of the unit Fig. 9. Fig. 11 gives the crank setting, the cranks being 110 deg. apart and so set that in the normal running range of positions only a small advance of the admission accompanies a considerable adjustment of the cut-off. By introducing side play into the cam-shifting gear the admission is actually maintained constant for a large range of cut-offs.

Turning next to the question of reversing, the cams have naturally to be given appropriate settings in this movement in order that the steam events may occur at the right time and in correct sequence. We will take the exhaust first. In this instance, the change is secured merely by allowing the driving dogs mentioned above to move through 50 deg. and drive from the other end of the circular slots in the cam. This will be clear from Fig. 12. The change in the case of the admission is a little more complex, and involves a change over of the functions of the two cams. Thus the cam B which in forward running governs the admission, in reverse running controls the cut-off, while C, which is the cut-off cam for forward running is the admission cam in reverse. The correct phase adjustment is arranged for by the amount of angular movement given to the small double crankshaft, and by the amount of lost motion introduced into the gear by making the discs D and E of a different width on the rim from the collars or bridles which move them longitudinally on the shaft. In the diagram, Fig. 11, the discs D and E are shown with flanges, but in the drawing, Fig. 3, they are shown with broad flat faces which the bridle rings overlap, while inside is arranged a ring which limits the play.

On the Continent the system of counter-pressure braking is often adopted and it is allowed for in this gear. This operation involves admitting steam to the cylinders much in advance of the ordinary lead position so that it is compressed by the engine. With this gear this early admission is clearly easily obtainable by a movement of the double crankshaft, advancing the admission cam. When, however, the admission cam is advanced to the extent required it becomes necessary to make a corresponding adjustment for the exhaust so as to ensure the latter being closed before the admission is opened. This is secured by a method of interlocking which is effected by the two long rods which extend through the gear to the cam A from the cams B and C. These two long rods engage in a circular slot in the exhaust cam, which is of such a length that when the admission is advanced to more than the usual running position, in order to produce the counter-pressure braking effect, the exhaust cam is driven by the rod and slot instead of by the dog on the shaft collar. Since, in reversing, the functions of the two cams B and C are changed over, it is necessary that a long rod be provided through to the exhaust cam from each of the cams B and C, and when using the counter-pressure brake, running trailing end first, the second long rod drives the exhaust cam in a manner corresponding to the forward drive which is described above.

THE OPTICAL SOCIETY.

A meeting of the Optical Society was held at the Imperial College of Science and Technology, on Thursday, April 12, 1923, the president, Professor A. Barr, D.Sc., LL.D., in the chair. The following papers were read and discussed:—

(1) "*The Hilger Microscope Interferometer*," by Mr. F. Twyman, F.Inst.P. The Hilger microscope interferometer is a development of the Hilger lens interferometer, and is used for measuring the aberrations of microscope objectives. A collimated beam of monochromatic light is separated into two beams at the transmissively silvered surface of a plate of plane parallel glass. The transmitted beam passes through the lens under test, and is reflected back from the surface of a convex mirror which is so disposed as nearly to coincide with the approximately spherical wave front of the light as it converges after passage through the lens. Thus after reflection and passage back through the lens under test, the wave front of the returning beam is approximately plane. The second beam, which may be called the comparison beam, is reflected back along its own path by a mirror so that the two beams recombine at the silvered surface of the plane parallel plate. Portions of each beam then pass on together through a lens which concentrates them on the eye of the observer. Under proper conditions the observer then sees an interference pattern apparently located on the surface of the lens under test, and this pattern is a contour map, to a scale of half wave lengths of the light used, of the aberrations of wave surface occasioned by passage through the lens under test of a plane wave. The arrangement may be modified by the use of a concave mirror instead of the convex one. A number of possible arrangements are discussed and an actual instrument is described in detail. The routine of setting up an objective for test is also detailed.

(2) "*On the Form of the Wave-Surface of Refraction*," by Mr. A. Whitwell, M.A. The graphic method used by Professor R. W. Wood and described in his "Physical Optics" for investigating the wave-surface of reflection is applied to the wave-surface of refraction. A series of wave-surfaces is drawn for each of a number of refracting surfaces or lenses. The incident waves are either diverging or converging spheres or planes at right angles or oblique to the axis; the refracting surfaces are plane, spherical, surfaces of revolution of which the sections are conics, or toric surfaces; the effects of spherical aberration, coma and astigmatism are illustrated. Each series of wave-surfaces consists of the following forms which always follow each other in the same order.

1. Saucer type, convex to the incident light when the refracted pencil is converging and concave when the pencil is diverging.

2. Saucer with inturned edges; like the last type, but the edges of the wave surface which have passed through the primary focus are concave towards the incident light when the refracted pencil is converging.

3. Closed surface type; the wave-surface is completely closed like a cone with a dished bottom, the axis of the cone being coincident with the optic axis.

4. Goblet type; somewhat like a champagne glass set sideways, the bowl being towards the incident light and the base towards the secondary focus. As we proceed towards the focus the bowl increases and the base diminishes.

5. Basin type. The base of the goblet has disappeared and just beyond the focus the surface is like a basin concave towards the incident light.

Some general properties of the wave surface are deduced from an examination of the drawings.

The difference of phase of disturbances propagated along a marginal and an axial ray is shown to be represented on the diagrams by the axial length of the closed-surface type of wave-surface or by the axial lengths of the bases of the goblet type.

The diffraction spectra are found in the neighbourhood of the edges of the saucers, of the apex of the closed-surface type and the rims of the goblet and basin type. Interference patterns are shown to occur in the region bounded by the caustic and by the extreme marginal rays. By drawing wave-surfaces half a wave-length apart lines of maximum and minimum intensity are found which are the sections of surfaces of revolution on which the intensity is a maximum or minimum. Sections of these surfaces by a plane at right angles to the axis show interference rings. Expressions for the distances apart of the rings are given.

The goblet type of wave-surface always occurs between the focus for marginal rays and that for paraxial rays, and may be called the characteristic of the focus.

Mr. J. H. Barton exhibited and described "A New Research Microscope of Original Design," embodying many novel features to ensure rigidity and ease of adjustment.

Directory for the Glass Industry, 1923.—This directory, the first issue, covers the glass industry in all its branches, giving as it does not only the names of manufacturers, the address of their works, their specialities, &c., but also the names of wholesale dealers in glassware, those of manufacturers of every component part of a glass factory, and so forth. It has been compiled by Mr. G. S. Duncan and Professor W. E. S. Turner and is published by the Society of Glass Technology, Dartnall-road, Sheffield. Professor Turner explains that the directory has been issued by the society following upon very numerous inquiries as to sources of supply of glassware, raw materials and plant; moreover, the society being the first organisation to bring all sections of the industry together, the directory will help, he adds, to strengthen the union of all concerned. The departure is a very interesting one and might perhaps be followed by other institutions.

"POWER STATION FUEL CONSUMPTIONS."

To the Editor of Engineering.

Sir,—*Apropos* of your article *re* the above, in April 13 issue, small wonder that "Super" stations have fizzled out, especially when the country is passing through such an economic crisis, if that is the best these electric crazeologists have to put in the front row.

With regard to the 100 to 200 million unit stations, with a consumption of 2·41 lb. of coal per unit generated, these appear to be giving a lower efficiency than the 10 to 25 million unit stations. The thermal efficiencies of the larger stations are apparently not given. The only inference that can be drawn from that, is that they cannot stand the limelight.

With regard to the 10 to 25 million unit stations, with a consumption of 2·04 and 2·19 (average 2·11 lb. of coal per unit generated) with a thermal efficiency of 15·20 and 14·95 (average 15·07 per cent.).

Then 1 h.p.-hour = 2,564·766 B.Th.U.
One unit = 1·34 h.p.-hours = 3,436·786 B.Th.U.

$$\text{Therefore } \frac{3{,}436{\cdot}786 \times 100}{15{\cdot}07 \times 2{\cdot}11} = 10{,}808 \text{ B.Th.U.}$$

Therefore, calorific value of coal used = 10,808 B.Th.U. What kind of coal is that?

It is well known that the average calorific value of coal, is approximately 50 per cent. above that figure, which, simply reduces their thermal efficiency to 10 per cent. on the face of it. That also is well known to be about the best they can do. In plain language that means, that for every ton of coal that goes into the generating station, not more than is equivalent to 2 cwt. passes out at the other end, as saleable current.

If it wasn't for that class of people in the world, who are obsessed with the idea of doing everything by simply pressing a button, regardless of cost, then, I suggest that very few generating stations would be required. Putting the world right, will never be accomplished through the medium of separating positive electricity, from negative, at that price.

Yours faithfully,
"Convinced."

[We cannot find either in our article or in the Report of the Electricity Commission, upon which it was based, any grounds for our correspondent's suggestion that the largest power stations, with outputs from 100 to 200 million units are less efficient than stations of 10 to 25 million units output. The facts are indeed quite opposed to this view, for they show a decided advantage in the larger stations. Stations of over 200 million units, consumed on an average 2·10 lb. per unit, the best of such stations having a consumption of 1·74 lb. and a thermal efficiency of 17·20 per cent. Stations between 100 and 200 million units had an average coal consumption of 2·41 lb., the lowest consumption being 1·98 lb. and the highest efficiency 15·25 per cent. For stations between 10 and 25 million units, the corresponding figures were 3·38 lb., 2·04 lb. and 15·20 per cent. The efficiency of stations below this size falls very rapidly, as we pointed out in our article. Furthermore our correspondent appears not to be familiar with the class of coal usually burnt in power stations. In cases where the Commissioners were not informed as to the calorific value of the coal used, they assumed a value of 10,500 B.Th.U. per pound, and we see no reason to question this figure. If there is any coal to be obtained in this country which "is approximately 50 per cent. above" the calorific value arrived at by our correspondent it is certainly not used in any power station.—Ed. E.]

The M.G.C. Manchester Year Book, 1923.—The present year book is the third annual issue by *The Manchester Guardian Commercial*, Guardian Buildings, Manchester. It contains in a small compass a large amount of information on Manchester and district, its trade, industries, commercial associations, &c. A "Who's Who" section gives particulars concerning well-known men, manufacturers, engineers, professors, and others in that part of England. The book closes with an alphabetical list of cotton mills, giving the names of their directors. This handy volume, which measures 7¼ in. by 5 in. and has over 160 pages, is well got up; its price is 2*s.* 6*d*, net.

Skinner's Cotton Trade Directory, 1923.—A very useful directory is one having the above title, edited and published by Messrs. Thomas Skinner and Co., Gresham House, E.C. 2, the well-known compilers and editors of "The Stock Exchange Year Book" and other publications. Since it deals with the cotton trade, one of the country's most important staple industries, it is sure to appeal to a very wide circle. The book opens with articles on raw cotton, and with particulars concerning its production and sale; on the cotton industry both in Great Britain and in leading countries of the world, including statistics and quotations for yarn, cloth &c. A financial chapter deals with cotton mill shares. Then follow chapters on the lace industry, the hosiery industry, information on the maintenance and driving of the textile factory, on spinning and weaving machinery, all of which are very complete. The directory portion covers the names and addresses of calico printers, bleachers, &c., of cotton spinning and manufacturing companies, lace companies, hosiery companies, directors, managers, and so forth, reference to the various sections being facilitated by tabs. The book measures 8¾ in. by 5¼ in., and contains over 1,500 pages. Its price is 12*s.* 6*d*. net. The experience of the editors is a guarantee of the accuracy of the information it contains.

CORROSION TESTS OF CERTAIN NICKEL ALLOYS.*

By F. Orme.

The alloys tested are: A, a "stainless" nickel alloy, of percentage composition 64 Cu, 35 Ni, 1 Sn; B, a "non-corrodible" nickel alloy, of 60 Cu, 40 Ni; C, the nickel-silver standard for spoon and fork manufacture, of the quality known as "seconds," containing 14 Ni, 30 Zn, 56 Cu. The tests were carried out on sheet metal, about ⅛ in. thick, left in the "as rolled" condition; the plates, 5 in. by 3 in., were suspended by means of drilled holes and strings in solutions of organic and mineral acids; the plates remained totally immersed for 14 days at room temperature, and were then re-weighed. The following is a summary of the percentage losses in the various acids, all of 5 per cent. concentration: In tartaric acid A lost 0·074 per cent., B 0·090, C 0·044; in acetic acid, A 0·092, B 0·109, C 0·094; in hydrochloric acid A 1·471, B 1·416, C 1·513; in sulphuric acid, A 0·151, B 0·361, C 0·381. There is thus very little difference between the three alloys, and the results tend to show clearly the incorrectness of the terms "stainless" and "non-corrodible" as applied to the alloys A and B. In the case of tartaric acid the ordinary standard nickel-silver is actually superior to these alloys in its resistance to corrosion. As regards acetic acid the losses in weight are practically identical for the three alloys; and even with the mineral acids the inferiority of ordinary nickel-silver to the other two alloys is not at all strongly marked. An examination of the surface appearance of the plates after immersion in the acids gives little information, except perhaps in the case of acetic acid. In that acid the plates of the alloys A and B appear to have retained their original surface lustre to a distinctly greater extent than the plates of nickel-silver.

Henslowe's Motor Dictionary—A pocket motor dictionary, in English-Spanish and Spanish-English, compiled by Mr. Leonard Henslowe, is issued by Messrs. Hirschfeld Bros., Limited, 263, High Holborn, W.C. 1, at the price of 5*s.* net. It gives a large number of motor car words in both languages, and should facilitate business connection between the United Kingdom and all Spanish-speaking countries.

Desulphurisation of Coke by Steam.—In the course of laboratory experiments in the desulphurisation of coke by steam, being conducted by the United States Department of the Interior, at the Pittsburgh, Pa., experiment station of the Bureau of Mines, steam tests at atmospheric pressure for the removal of sulphur from chunk size coke have been finished, with encouraging results. Combined sulphur as FeS, $FeSO_4$ and free sulphur (not including solid solution sulphur) in Ohio coke was reduced from 1·38 per cent. to 0·72 per cent. The solid solution sulphur was not affected, but it has been shown that this has very little effect in contaminating sponge iron in the blast furnace. In Illinois coke, 0·62 per cent. sulphur corresponding was reduced to 0·48 per cent. Clairton coke low in sulphur was reduced from 0·29 per cent. to 0·17 per cent. Sulphur in a sample of gas-house coke from Philadelphia was reduced from 0·81 per cent. to 0·60 per cent. These results were obtained without application of vacuum, which may reduce still further the amount of sulphur. Very little steam is required—3 grammes of steam per gramme of coke per hour were employed, which is a big excess. Iron will be heated in contact with the treated coke and the transfer of sulphur determined.

Radiology at the Manchester Royal Infirmary.—What is probably one of the most up-to-date and comprehensive X-ray installations in the country has recently been completed at the Manchester Royal Infirmary, the work having been carried out by Messrs. Watson and Sons (Electro-Medical), Limited, 43, Parker-street, Kingsway, W.C. 2. The installation occupies the whole of the ground floor of one block of the buildings, and one of its special features is the inclusion of a demonstration room which is used for instructional purposes. Another room is set apart for fluorescent-screen examinations, and is provided with its own high-tension transformer from which the current is distributed through overhead tubing, instead of wires, in order to obviate brush discharges. A room divided into two sections is devoted to radiographic work, and a 2-kw. high-tension transformer is installed for supplying current to tubes for ordinary photographic or dental work. In connection with the former, it may be mentioned that the couch is fitted so as to permit of the automatic disposition of the tube box for stereoscopic work. Another room is divided into three separate cubicles, in each of which a patient can receive more or less prolonged therapeutic treatment by X-rays, and for specially deep therapy, such as is employed for the treatment of cancer, two complete equipments of the Erlanger type are installed in a separate room; Coolidge tubes, it may be mentioned, are used for the whole of the work. The department includes a photographic dark room and a workshop in which minor repairs to apparatus can be carried out, as well as a consulting room and dressing cubicles for patients. Messrs. Watson have issued a booklet illustrating and describing the installation, and this publication should prove particularly useful to persons interested in the application of X-rays to medical requirements.

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* Abstract of a contribution to the discussion on "Alloys Resistant to Corrosion," held jointly at Sheffield by the Faraday Society, the Sheffield Section of the Institute of Metals, and the Manchester Metallurgical Society, on Friday, April 13, 1923.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Though there are still many weak patches, noticeably in those sections dealing with the production of high-grade steels, the position in the steel and engineering trades continues steadily to improve. Sheffield's total of unemployed is now approximately 30,000, whereas in Rotherham, owing to the benefit resulting from the big increase in orders in mild steel, unemployment has fallen from 10,000 at this time last year to approximately 1,200. Machinery makers report an encouraging number of inquiries, though there is delay in placing orders, owing, to some extent, to the unsettled state of the labour market. The indefinite outlook in the building trade has caused a temporary set-back in the demand for brickmaking machinery. More inquiries are also coming forward for steel-works plant, and there is a slightly better tone in agricultural machinery, castings, forgings and cutting parts for agricultural implements. Virtually all the open-hearth steel furnaces in South Yorkshire are working at full capacity. Current activity is mainly based on contracts placed some months ago. Business in mild steel is at a distinctly lower pace owing to the high prices of raw and semi-finished materials and the uncertainty of the Continental position. Buyers are placing only sufficient new business to cover immediate commitments, hoping that any favourable developments in the Ruhr situation will bring with it a recurrence of competition and will reduce values of British produced material, which they contend are excessive. The scarcity of steel scrap is unrelieved, and prices are universally high. Heavy melting basic steel scrap stands at 105*s.* per ton delivered Sheffield works; low sulphur and phosphorous acid steel scrap at 130*s.* per ton; heavy wrought-iron scrap and machinery cast-iron scrap each 110*s.* per ton, and cast-iron scrap 85*s.* and 92*s.* 6*d.* Though crucible steel makers are still badly in need of work, an improved tone prevails in high-speed twist drills. The operation of the Fordney Tariff has not completely stifled Sheffield's connection with the United States. Wagon builders are busy. Makers of axles, tyres, springs and buffers are well booked forward.

South Yorkshire Coal Trade.—The shortage of blast-furnace coke, coupled with the growing demand for export, has caused a further rise in prices. Quotations for special deliveries are mentioned as high as 60*s.* to 70*s.* per ton. Best steam hards maintain their recent advance, with collieries well booked forward. The position will materially improve when new wagons now under construction are available to relieve congestion at ports. There is a strong inquiry for all classes of smalls. Cobbles and nuts are a rising market. House coal remains unchanged. Quotations:—Best branch handpicked, 32*s.* 6*d.* to 34*s.* 6*d.*; Barnsley best Silkstone, 28*s.* to 30*s.*; Derbyshire best brights, 25*s.* 6*d.* to 27*s.* 6*d.*; Derbyshire best house, 23*s.* to 24*s.* 6*d.*; Derbyshire best large nuts, 20*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 21*s.*; Yorkshire hards, 22*s.* to 24*s.*; Derbyshire hards, 21*s.* to 24*s.*; rough slacks, 12*s.* to 14*s.*; nutty slacks, 10*s.* 6*d.* to 12*s.* 6*d.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is difficult to arrange. Merchants have no iron to offer, and makers are practically fully sold to the end of June. Output is going into consumption as it is made, and buyers and sellers alike show disinclination to negotiate on forward account. Occasional Scottish inquiries for supplies beyond the first half of the year are reported, but so far as is ascertainable they do not result in much business. Notwithstanding continued scarcity of Cleveland pig-iron values show rather marked downward tendency. Though sellers still ask 132*s.* 6*s.* for No. 1 and 127*s.* 6*d.* for No. 3, the former is said to be obtainable in small lots at 130*s.* and the latter has been sold at 125*s.* No. 4 foundry is now no more than 122*s.* 6*d.*, and No. 4 forge is quoted 117*s.* 6*d.*

Hematite.—Merchants have still a little East Coast hematite to take up, but makers are well sold. Buyers, however, are very backward, and in the continued absence of transactions values are weakening. So scarce is No. 3 quality that in delivery of parcels of mixed Nos. producers are having to include an unusually large proportion of No. 1 to fulfil their obligations to customers. Nos. 1, 2 and 3 are quoted 122*s.* 6*d.* to 125*s.*

Foreign Ore.—Sales of foreign ore are very little heard of. Consumers are quite independent of the market, having fairly large stocks, and good supplies to come forward against contracts. April imports are heavy. Best rubio is said to be obtainable at 24*s.* 6*d.* c.i.f. Tees.

Blast-Furnace Coke.—The situation as regards blast-furnace coke shows no change. There is still acute scarcity, but makers are renewing contracts with local regular customers on the basis of 42*s.* 6*d.* for medium Durhams delivered.

Manufactured Iron and Steel.—There is a decidedly quieter feeling in finished iron and steel. Demand is falling off, but manufacturers show great reluctance to make price concessions. Common iron bars are 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel billets (soft), 10*l.*; steel billets (medium), 10*l.* 10*s.*; steel billets (hard), 10*l.* 15*s.*; steel boiler plates, 14*l.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.* to 10*l.* 5*s.*; heavy steel rails, 10*l.* 10*s.*; fishplates, 14*l.* 10*s.*; black sheets, 15*l.*; and galvanised corrugated sheets, 19*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The conditions in the Scottish steel trade have varied very little of late and nothing much in the way of fresh business has been fixed up. Buyers are very slow to enter the market, and on the other hand sellers are not pressing very hard for orders, as prices are not over remunerative at present. The business now on the books amounts to a fairly large tonnage overall and ensures the plant in commission running steadily for a month or two, but industrial troubles are likely to arise again and once more dislocate trade. Shipbuilding material continues very slow, but sectional stuff is moving quite freely. In the black sheet trade conditions may be considered very fair and while there is a lull in home buying there is good business passing on export account. The galvanised branch of the industry is doing very well at the moment and makers have a fair amount of business booked. Prices all round are firm and the tendency is upward rather than otherwise. The following are the current quotations:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—In the West of Scotland malleable iron trade there has been little change during the past week or two. Orders on hand are sufficient to keep plant employed, and the recent advance in price, while causing a slight check to business, has scarcely made any appreciable difference overall. Inquiries are fairly good and in the steel re-rolling branch a fair amount of activity is general. Quotations are firm round 12*l.* 10*s.* per ton for "Crown" bars, delivered Glasgow stations.

Scottish Pig-Iron Trade.—A quieter tone is being felt in the Scottish pig-iron trade and forward business is not so plentiful as it was. Nevertheless the current output is all earmarked and is going away as quickly as it is available. For foundry grades there is not quite so heavy a demand and prices have an easier tendency, with No. 1 at 6*l.* 2*s.* 6*d.* per ton and No. 3 at 5*l.* 17*s.* 6*d.* per ton, both on trucks at makers' yards. Hematite has been doing fairly well of late and delays to the steel works have been on quite a reasonable scale, but of course there is much room for improvement. The price is now 6*l.* 7*s.* 6*d.* per ton delivered at the steel works, but consumers are not inclined to place orders for their future requirements at to-day's quotation and seem rather disposed to run the risk of the market going against them.

Scottish Pig-Iron Shipments.—The shipment of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, April 21, amounted to 3,650 tons, of which 3,540 tons went foreign and 110 tons coastwise. For the corresponding week of last year the figures were 389 tons foreign and 35 tons coastwise.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—There has been a falling-off in the demand for coal. Prices though showing an easier tendency have not fallen to any material extent because of the fact that collieries are well sold and amply supplied with shipping. In fact, there is more shipping to hand than can be comfortably dealt with by the dock company. The docks are full of vessels, and in addition there is daily a fleet of about 40 boats in the roadsteads waiting to come into dock. Best Admiralty large coal is steady at 40*s.*, with seconds 1*s.* to 2*s.* less, while the leading Monmouthshires command up to 40*s.*, with Eastern Valleys round 37*s.* 6*d.* Small coals are more freely available than has been the case for some time past, and the best descriptions are now offered at 30*s.*, with other grades in proportion. The effect of the occupation of the Ruhr Valley and the consequent increased demand for Welsh coal is reflected in the official returns showing the volume and value of South Wales coal exports in March. It is shown that the quantity shipped from Cardiff, Newport, Swansea and Port Talbot, in March, was 547,900 tons more than in the corresponding month of last year, and the value 810,800*l.* higher. Compared with February last there is an increase of 402,000 tons and 589,800*l.* In all 2,697,788 tons were exported, valued at 3,351,965*l.*, or an average of 24*s.* 10*d.* per ton, or 7*d.* more than in February. The value of large steam coal shipped in March worked out at 27*s.* 8*d.*, compared with 26*s.* 10*d.* in February, and that of steam small 19*s.* 2*d.* against 17*s.* 11*d.*, representing an increase of 10*d.* and 1*s.* 3*d.* respectively. On the other hand, anthracite prices fell 1*s.* 3*d.* per ton, that of large dropping to 34*s.* 3*d.* in March and small 18*s.* 10*d.* The volume of exports last week totalled 577,300 tons, or 150,000 tons less than in the preceding week. Of the total, 211,200 tons were despatched to France, 132,700 tons to Italy, 50,900 tons to South America, 26,500 tons to Spain, 32,700 tons to Portugal, 19,600 tons to Greece, 23,200 tons to British coaling depôts, 15,100 tons to Belgium, 19,100 tons to Holland, 23,900 tons to Germany and 21,800 tons to other countries.

Iron and Steel Trade.—Business in the Welsh tin-plate trade has been conducted on quiet lines during the past week and the tendency of prices is towards lower levels, with current values from 24*s.* 3*d.* to 25*s.* per box. Shipments of tin plates last week amounted to 9,800 tons, compared with 11,300 tons in the previous week; black plates 2,900 tons, against 5,300 tons; galvanised sheets 2,500 tons, against 3,300 tons; and other iron and steel goods to 260 tons, against 12,000 tons.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, April 27, at 7.30 p.m., at 39, Victoria-street, S.W. 1, Lecturette, "Stock Control," by Mr. J. Fearn. Friday, May 4, at 7.30 p.m., at 39, Victoria-street. Lecturette, "Alternating-Current Neutral Point Earthing," by Mr. S. A. Stigant (Member). Slides.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, April 27, at 7 p.m. Informal Meeting. Adjourned discussion on "The Use of Light Alloys in Place of Iron and Steel," opened by Mr. A. E. L. Chorlton, C.B.E.

THE INSTITUTE OF METALS: SHEFFIELD LOCAL SECTION.—Friday, April 27, at 7.30 p.m., in the Mappin Hall of the University, St. George's-square. Annual General Meeting.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Saturday, April 28, at 7.30 p.m., at the Education Offices, St. James'-road, Dudley, when a paper will be read by Mr. J. H. Grindley, D.Sc., M.I.Mech.E., on "Repeated Stress Testing." Preceding the above meeting the Annual Meeting for the election of Officers, &c., will take place. The chair to be taken at 7 p.m.

THE INSTITUTION OF PROFESSIONAL CIVIL SERVANTS.—Monday, April 30, at 6 p.m., in the Meeting Hall, Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W. 1. (1) Presidential Address by Sir Richard Redmayne, K.C.B.; (2) to receive the Annual Report of the Council and Financial Statement; (3) Election of Vice-Presidents of the Institution.

THE ROYAL SOCIETY OF ARTS.—Monday, April 30, at 8 p.m. Howard Lectures, "The Development of the Steam Turbine," by Mr. Stanley S. Cook, B.A.(Cantab.), M.I.N.A., M.I.M. (Parsons Marine Steam Turbine Company). Lecture I.

THE INSTITUTE OF METALS.—Wednesday, May 2, at 8 p.m., at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W. 1. Annual May Lecture, by Dr. W. Rosenhain, F.R.S., Vice-President, on "The Inner Structure of Alloys."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—WIRELESS SECTION MEETING.—Wednesday, May 2, at 6 p.m., in the Lecture Theatre of the Institution. "The Design of Inductances for High-Frequency Circuits," By Professor C. L. Fortescue, Member.

THE INSTITUTION OF SANITARY ENGINEERS.—Thursday, May 3, at 6.30 p.m., at Caxton Hall, Westminster, S.W. 1. Paper on "The Relationship between Insanitation and Disease," by Mr. Walter R. Hadwen, M.D., L.R.C.P., M.R.C.S.

THE CERAMIC SOCIETY: REFRACTORY MATERIALS SECTION.—Thursday and Friday, May 3 and 4, at the Town Hall, Bournemouth. Thursday, May 3, at 10 a.m.: "The Geology of the Bournemouth District," by Mr. H. Dewey; Lecture, "The Physical Properties of Clay," by Mr. A. S. E. Ackerman, B.Sc.; "The Use of Refractory Materials in Gas Works," by Mr. G. M. Gill; "Note on the Abrasion of Fireclay Materials," by Mr. W. C. Hancock, B.A.; "Notes on the Mineralogy of Ball Clays," by Mr. A. Scott, D.Sc., M.A.; "The Behaviour of Clays, Bauxites, &c., on Heating," by Professor J. W. Cobb, B.Sc., F.I.C., and Mr. H. S. Houldsworth. Thursday evening, at 7.30 p.m.: Dinner at the Grand Hotel, Bournemouth. Friday, May 4, at 10 a.m.: General Meeting. "Dolomite," by Dr. L. M. Parsons, D.I.C., F.G.S.; "The Manufacture of Refractories in America," by Mr. A. F. Greaves-Walter. Visits to Works.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 4, at 9 p.m., a discourse will be delivered by Mr. Frederick Soddy, F.R.S. The subject is "The Origins of the Conception of Isotopes." Afternoon Lecture, at 3 p.m. Thursday, May 3, Professor J. T. MacGregor-Morris, M.I.E.E., M.R.I., on "Modern Electric Lamps: (II) Glowing Solids in Gases."

THE INSTITUTE OF METALS: SWANSEA LOCAL SECTION.—Friday, May 4, at 7.15 p.m., in the University College, Singleton Park, Swansea. Annual General Meeting.

THE INSTITUTION OF CIVIL ENGINEERS.—Friday, May 4, at 6 p.m. The twenty-ninth James Forrest Lecture, entitled, "The Interdependence of Abstract Science and Engineering," by Sir Richard T. Glazebrook, K.C.B., F.R.S., Hon.M.Inst.C.E.

VACUUM ARC FOR VISIBLE AND SOFT X-RAYS.—The simple vacuum-arc arrangement for spectroscopic work in visible as well as in soft X-radiations, described by H. Nagaoka and Y. Suguira of Tokyo, in the March number of the *Astrophysical Journal*, makes use of a somewhat novel type of Wehnelt cathode. A carbon rod is dipped into a solution of nitrate of barium (or strontium) and then heated in the Bunsen flame so that the carbon becomes covered with a layer of barium oxide. This cathode is fitted into a glass bulb of ordinary X-ray type which is joined to a Gaede pump. The cathode is fixed into one of the three necks of the bulb by means of a rubber stopper; inside the bulb the carbon is sheathed with a silica tube, and a stout copper wire is screwed into the carbon for connection. The anode is another silica tube in which the salt or metal to be tested lies on another carbon rod; the seals are made by means of Kholinsky cement. Opposite the anode is a neck closed by a quartz prism. The bulb is started with a low-tension current of 150 volts or less; when the glow appears in the bulb, the connections are switched to the poles of a direct-current generator of 500 volts or more.

REINFORCED-CONCRETE OVERBRIDGE AT NEEPSEND SHEFFIELD.

CONSTRUCTED BY MESSRS. K. HOLST AND CO., ENGINEERS, WESTMINSTER.

(*For Description, see Page* 514.)

FIG. 40. VIEW SHOWING ARCH-RIB SHUTTERING AND FALSE WORK.

FIG. 41. THE 35-FT. PRE-CAST SECTION BEING SLUNG.

FIG. 42. CRANE LIFTING THE PRE-CAST SECTION INTO POSITION.

FIG. 43. THE PRE-CAST SECTION PLACED ON FALSE WORK SUPPORTS.

Fig. 42. Crane Lifting the Pre-Cast Section into Position.

Fig. 43. The Pre-Cast Section placed on False Work Supports.

THE CAPROTTI LOCOMOTIVE VALVE GE

(For Description see Po

Fig. 1.

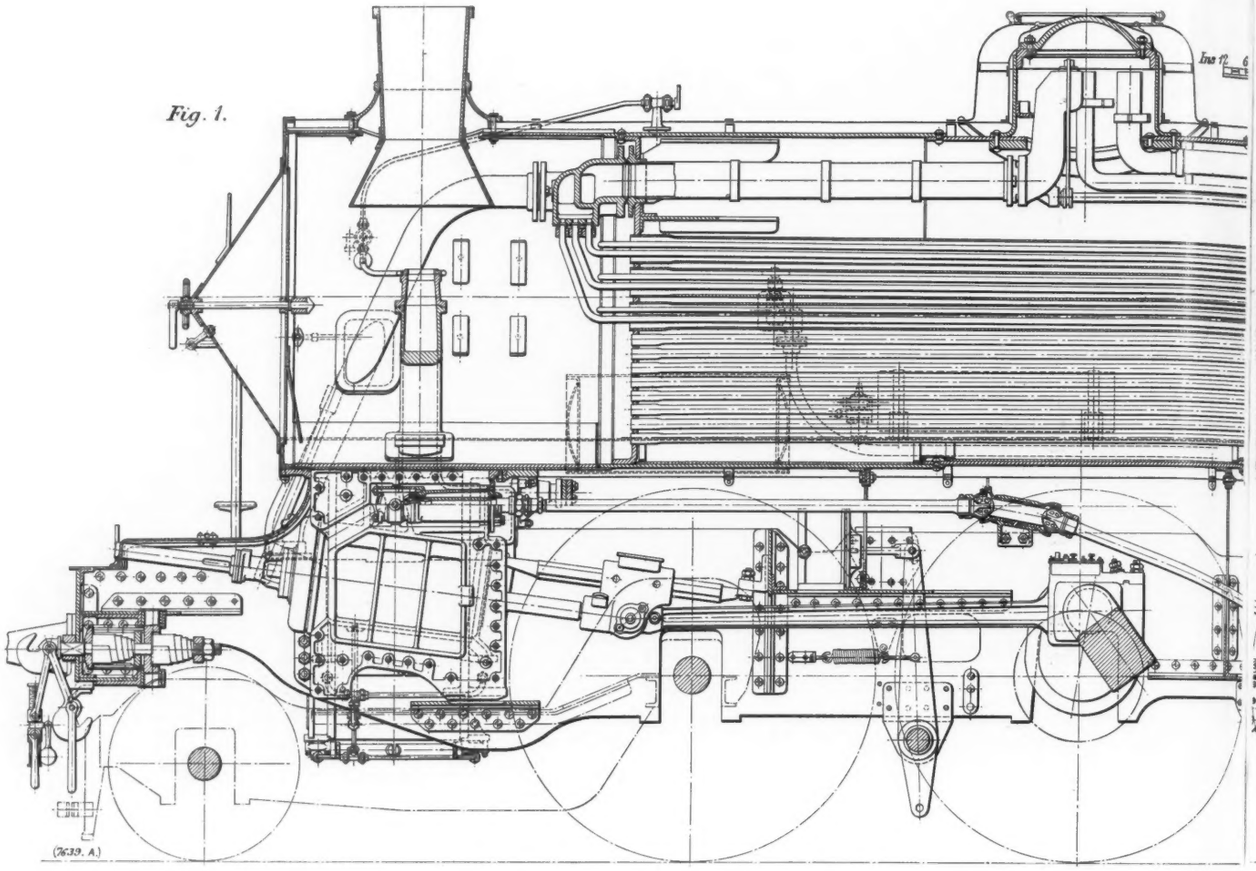

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Fig. 3.

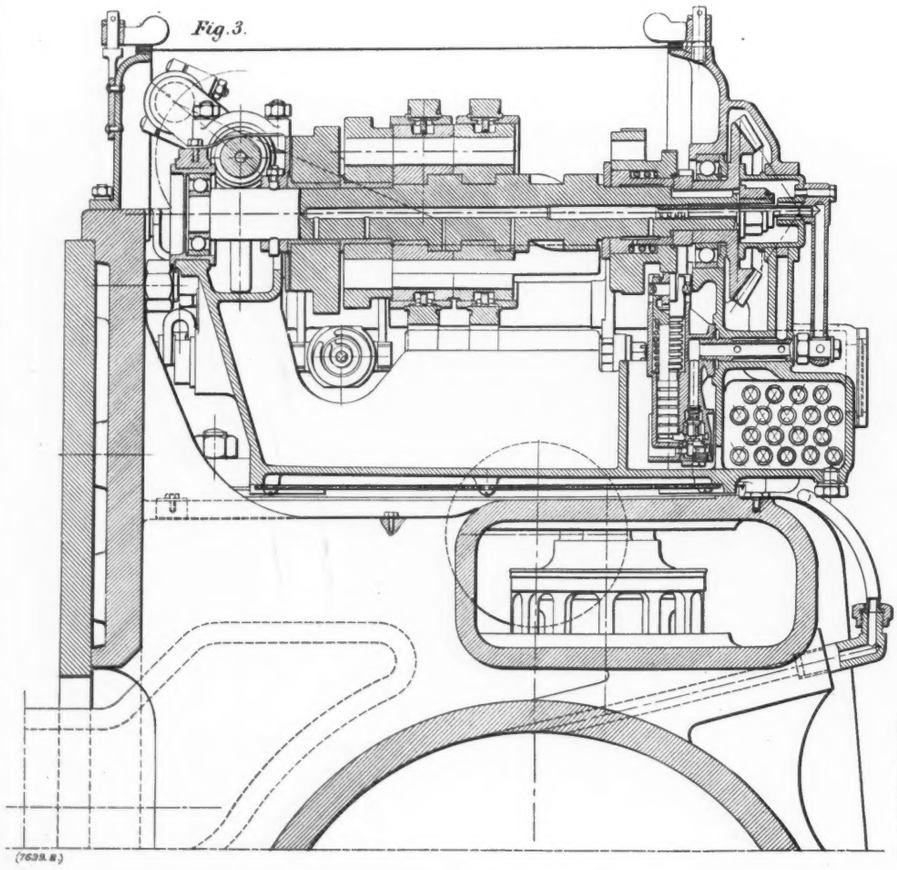

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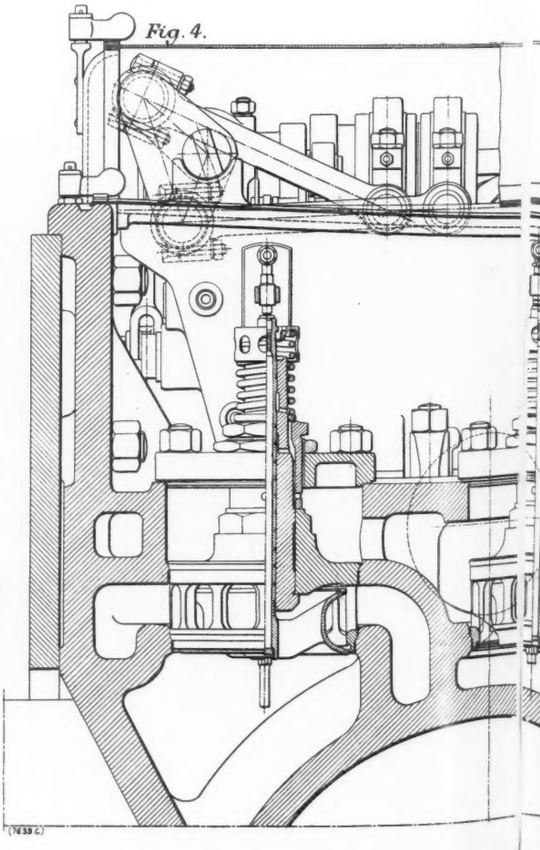
Fig. 4.



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GEAR; ITALIAN STATE RAILWAYS.

(see Page 522.)

Scale for Fig's 1 & 2.

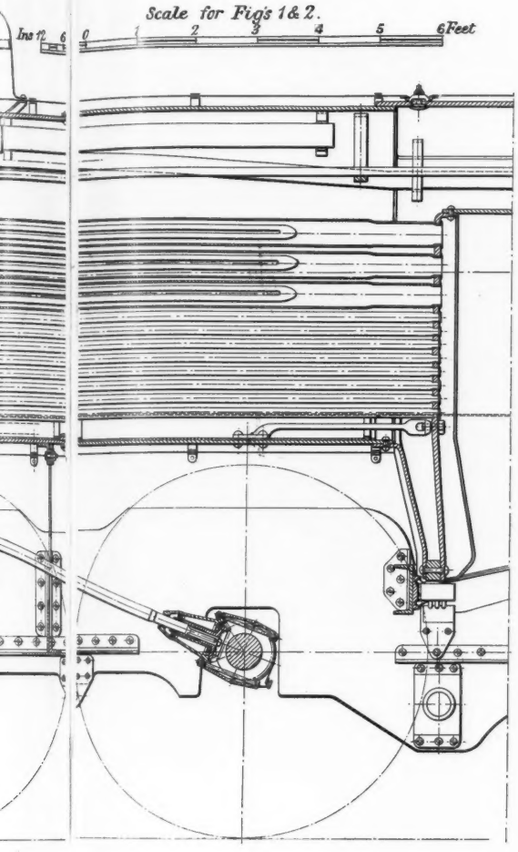
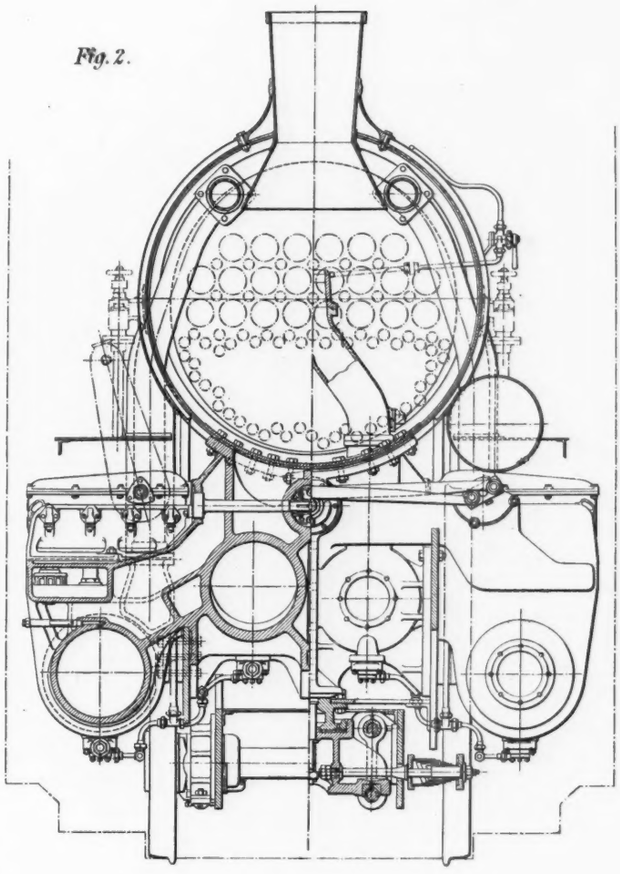
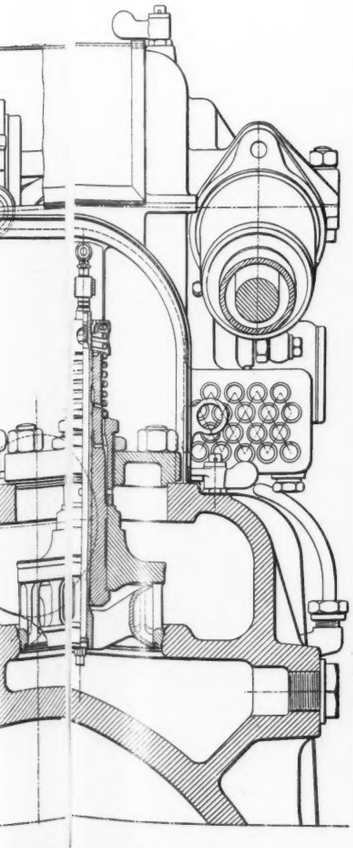


Fig. 2.

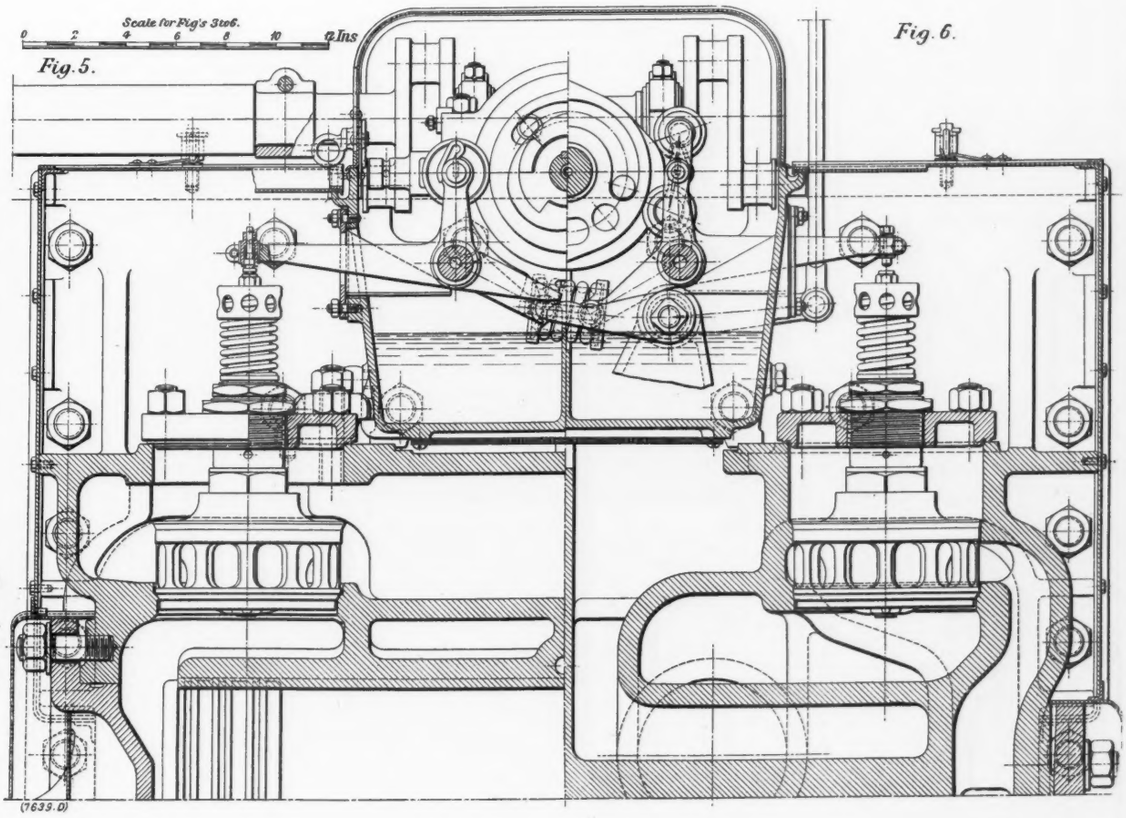




Scale for Fig's 3 to 6.

Fig. 5.

Fig. 6.



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ENGINEERING.

FRIDAY, APRIL 27, 1923.

THE QUALITY OF HARDNESS.

ORDINARY language is crowded with words relating to ill-defined notions, the lack of exactness of which is no particular drawback in ordinary conversation. Hardness is a word of this kind. Everybody knows, in a general way what hardness means, and the statement that one thing is harder than another indicates a relationship which the mind quite readily accepts as intelligible. But the simple question of how much harder one substance is than another, shows at once the looseness of the conception. It brings out clearly the fact that it is necessary to scientific thought that there shall be definite units in which to think, for otherwise the mind wanders in a maze of shadowy ideas. The engineer has units of pressure, velocity, elasticity, &c., all of which can be expressed if desired, in terms of the ultimate and fundamental units of length, mass and time. Indeed, unless any property of matter can be so expressed, he is loath to allow it any objective meaning, regarding it as a question rather for the metaphysician or the psychologist, than as coming within the range of physical fact. Hardness, however, is unquestionably an objective characteristic, and however complex may be the unit which would measure it, such a unit must exist and must be ultimately expressible in terms of length, mass and time.

To find out exactly what hardness is, and to state its measure in the fundamental units is a work of pure science, which no one seems yet to have attempted. The first step in the process, is for some physicist with insight, a type of man which this country fortunately produces fairly frequently, to frame a hypothesis based on what is known of molecular physics, and consistent with the various phenomena of hardness. The confirmation of the theory, by experimental verification of the conclusions which logically follow from it, is a matter for the commonplace type of careful research worker, and can be carried out in any physical laboratory provided with the necessary equipment. The absence of any theory of what constitutes hardness is significant of the complexity of the characteristic of materials which is denoted by the term. The hardness of ivory is different from the hardness of lead, and this again is different from that of india-rubber, yet any definition of hardness, which is to be as scientifically precise as that of temperature density or elasticity, for example, must be applicable equally to all substances. Whether such a definition would be of practical value or not is beside the point. Science aims at the generalisation of facts, and it is as unsatisfactory to the mind to have one kind of hardness for metal and another for india-rubber, as it would be if various substances all had their peculiar kinds of temperature or weight.

Hardness is so important a property of many of the materials used in engineering work that in the absence of any effective help from theoretical considerations, engineers have been compelled to deal with it on strictly empirical lines. If a piece of steel was so hard that a file would not scratch it, it was "hard" and there were no degrees of hardness beyond this point. Softer material was graded roughly into two or three classes according to the ease with which it could be machined. All this, of course, was grossly "unscientific," yet it served fairly well to meet ordinary workshop requirements. Indeed, even to-day a modification of the file test is relied on in preference to all other methods to detect unsatisfactory hardening in certain kinds of work of the highest class. In due course various tests were devised with the idea of giving some numerical values to different degrees of hardness. Of these the best known is the Brinell test, which depends upon the indentation of the material by a steel ball pressed into it. In the Ludwik test, used on the Continent, a cone-shaped point is used instead of a ball. The Scleroscope test relies upon the rebound of a falling hammer as a measure of hardness. Mr. E. G. Herbert has recently devised an instrument whose indications of hardness depend upon the time of oscillation of a compound pendulum, and last Friday evening a test of hardness depending upon the width of a diamond scratch was discussed by the Institution of Mechanical Engineers.

If all these tests are true measures of hardness it follows logically that there must be some consistent relationship between them, so that their indications are convertible into the same scale of hardness. A vast amount of labour has been expended in the endeavour to establish mutual relationships between many of them, but with little real success. The papers read before the Institution of Mechanical Engineers and published elsewhere in this issue, emphasise the unsatisfactory condition of the whole question. The Brinell test, according to Professor Turner, will show that a piece of hard rolled copper may be harder than a piece of mild steel, yet the steel will cut the copper and the copper will not cut the steel. Moreover, any test which requires delicate microscopic measurements has obvious drawbacks. The scleroscope test is simple enough, but the fact that it cannot differentiate between hardened and unhardened steel balls of certain sizes, shows that other factors besides hardness control its indications. One turns with little more hope to the scratch test as described last Friday, as a general solution of the problem of measuring hardness. This test, like others, will no doubt have its uses in a particular field, but the field is likely to be a very limited one. Even if diamonds ground to standard angles could be commercially obtained, and a reliable scratching instrument could be devised, the measurement of the width of the scratches to the accuracy required by means of a high power microscope is not for the ordinary workshop.

Exactly what property of the material the scratch test measures is by no means clear, but this is a defect common to all the other hardness tests. It has nothing in common with the old mineralogical hardness test which graded a material according to whether it would scratch or be scratched by any member of a series of standard materials. The point of a diamond will, of course, scratch anything, so that there is nothing comparative about the diamond scratch test except the size of the scratches a standard diamond will make under standard conditions. The first diamond point used in the experiments at the National Physical Laboratory was something like a blunt inverted pyramid, and as might have been expected the scratches were too ragged for accurate measurements to be made. They were, indeed, real scratches in the ordinary sense of the word. The next diamond tried was shaped something like a screw-cutting tool for

cutting brass, but, again as might have been foreseen, its action was to cut rather than to scratch the metal, and it "dug in" and cut wider and wider, exactly as a lathe tool would do under similar conditions. Finally, the diamond was reversed and the metal was dragged under it in the reverse direction, and under these conditions vee-shaped grooves were pressed in the test piece. It is the widths of these grooves, which are of microscopic dimensions, which it was the object of the research to correlate with the hardness of the material.

Until our physicists have come to some agreement as to what property of the molecules of a substance, or what configuration of these molecules gives the quality to a material which we connote by hardness, the subject will never be put on a really scientific basis. There are enough and to spare of so-called "hardness tests," and nothing is to be gained by devising any more. If a certain Brinell number, Scleroscope number, or scratch-width is found to be associated with the quality of material which is satisfactory for a certain purpose, then the particular number or width can be used as an acceptance test for the material. This, in fact, is what is done in practice, and further than this the engineer cannot go at present. In spite of all the efforts which have been made to justify the several tests by scientific considerations, they still remain empirical determinations of an unknown quantity. If hardness is wanted in a material for the resistance of abrasion, the amount of abrasion produced under given conditions is the only true measure of the kind of hardness required. If penetration is to be resisted, as in the case of armour plate, some kind of penetration or indentation test is obviously suggested. If, on the other hand hardness is taken as an indication of tensile strength, or of chemical composition, it is surely better, whenever possible, to determine these characteristics directly. The ease by which certain so-called tests of hardness can be applied to finished material without injuring it, and the pseudo-quantitative nature of the numerical results obtained, tend, by reason of their attractiveness, to disguise the fact that it is an unknown quantity which is being measured, and one which may, or may not, be correlated with the characteristics desired.

The experimental work which forms the subject matter of the two papers read before the Institution of Mechanical Engineers last Friday, was carried out at the National Physical Laboratory for the Hardness Tests Research Committee of the Institution. It is to be presumed that the experiments were devised in accordance with some definite programme of research, arranged for the purpose of collecting accurate data, from which ultimately some tenable hypothesis as to what constitutes hardness, may be deduced. Neither the authors of the papers, nor any representative of the Research Committee, indicated at the meeting that the experiments were directed towards the proof or otherwise of any existing hypothesis, or indeed, that any hypothesis at all had been formed as to the nature of the quality which it was desired to measure. Reticence in the formulation of hypotheses and theories is of all things to be commended, but it is now nearly a quarter of a century since Brinell devised a quantitative measure of hardness, and the accumulation of the results of hardness tests of numerous kinds is now so vast that it seems that the time has come for the physicist to step in. The invention of further hardness tests and the collection of additional uncorrelated data, is to be deprecated until some agreement can be arrived at as to the exact property of the tested material which is in question.

MACHINERY AND AGRICULTURE.

THE greatly increased interest taken in recent years in the use of machinery in agriculture has directly arisen from conditions during, and subsequent to, the war. During the war itself, when labour was drafted to other work, farmers were glad enough to get their work expeditiously performed by any means, and though often sceptical, after the manner of their conservatism, in the early stages of the innovation, remained to bless the tractor or machine which had helped them over a difficulty. Subsequent to the war the situation was affected favourably by various factors. Prices ruled high, and the mechanical instinct permeated all classes in a degree previously unknown. Numbers of men returned to this country with a far wider outlook on life than they had previously had, many of them having been in close touch with mechanical appliances or transport, and much more kindly disposed therefore towards machinery than formerly. At the same time military service assisted greatly in the development of robust design. The rough work to which tractors were put on all types of broken ground brought weak points to light, and this experience was of inestimable value in the task of improving the reliability and raising the standard of machines.

Against these influences must be set the difficulty a farmer has in obtaining information which will enable him to form a fair estimate as to whether a piece of machinery would be likely to prove a good investment. It has been with a view to meeting this requirement to some extent that trials have been held by the Royal Agricultural Society and by the Society of Motor Manufacturers and Traders, and demonstrations have been conducted by the Ministry of Agriculture. These tests, however, have not always proved quite satisfactory, and exactly three years ago we suggested in these columns that what was really wanted was something more on the lines of the R.A.C. trials for motor vehicles. This suggestion was made at the time of the issue of a report by a Departmental Committee on Agricultural Machinery.

The terms of reference of that committee were wide, and the report covered a very large field. In a more concise manner the subject has now been again reported on by a much larger committee, appointed by the Minister of Agriculture in November, 1921. The report is dated April 7, and in many ways is an advance on the previous one which, though more copious, was somewhat nebulous in character. Of the first committee all but two members sat on the body which has just reported, but the latter was considerably strengthened by many engineers and others. Its basic recommendations are connected with organisation, though it reports also on demonstrations, nature of testing to be undertaken, research, assistance to inventors and dissemination of information, &c. In brief the suggested scheme embraces a small permanent testing staff attached to the Ministry of Agriculture, an Advisory Committee to advise on testing and research work, and a programme of tests with the issue of certificates stating the actual performance of a machine.

The provision of the nucleus technical staff is a matter on which the committee is not in complete agreement. The question, however, is for the moment one of detail rather than principle, for it is on the adequacy of the provision and of the propriety of such staff forming part of the establishment of a Ministry that opinions differ, and not as to the necessity for it. One of the most interesting and, we are afraid, not wholly satisfactory, features of the proposals is concerned with the constitution of the proposed advisory committee which it is stated expressly is to be "representative of interested associations and institutions." The list of proposed representatives numbers 18, one body being represented by three members, four by two members each, the remaining members each representing some body or some class. The Ministry of Agriculture is rightly represented, as is also the Department of Scientific and Industrial Research. The other bodies are associations or unions representing the farmers, manufacturers of appliances, and labour. At the very bottom of the list comes "One representative of consulting engineers, selected by the Ministry."

It appears to us that in this list there is a serious omission. As we have said, it is intended to embrace associations and institutions interested, and it may well be asked how it is that the Institution of Mechanical Engineers is not given the most important place among these. As the sponsor for all mechanical developments of the country, this Institution is certainly entitled to a leading part in testing and research work connected with machinery on the farm. In fact, the most important trials since the war have all been conducted by eminent members of that body, and probably no one institution covers so well the whole field of mechanical appliances. It is true that the Institution of Automobile Engineers is also excluded, but it will be conceded that this latter body does not attempt to cover the wide range of machinery employed or capable of being utilised in agricultural processes. The "Mechanicals," however, do stand for this.

In his presidential address, delivered in 1922, Dr. Hele Shaw laid great stress on the fact that the Institution had been recognised and approached by the War Office, the Ministry of Education and other sections of the official world, and is now co-operating with them in matters of training and education. We believe a great many members will regret the fact with us, if official recognition of this "learned" institution is to be restricted to book learning. The practical side of engineering has always been a feature of the Institution, and in what more practical way could it be of assistance to the country than in helping to place the use of agricultural machinery on a better footing by improving the appliances and popularising their adoption. It is possible that when nominated the committee, if formed on the lines suggested in the report, might, and probably would, include several members of the Institution. It might even be that the one representative of consulting engineers happened to be a member. This, however, is not quite the point. The Institution exists in corporate form for, and is the most influential body in the country concerned with, the mechanical side of the arts, and its standing should be such that work of the kind proposed could be most effectively conducted only with its active support and co-operation. The traders and manufacturers are well represented, as are also the farmers and the farm workers. The engineering profession is virtually ignored. We do not know whether the Institution has been approached on this matter or not. To us the sphere of work seems from the practical point at least as useful as the granting of national education certificates. We trust that the body will make its voice heard on the subject, and that the council will see its way to urge upon the Government the desirability of officially enlisting its active co-operation, and of according to it adequate representation on any advisory or other committee which may be formed to deal either with tests, research, standardisation or other line of work which will tend to raise the quality or increase the utility of agricultural machinery of all classes.

The scheme of work proposed covers what the report terms series investigations as well as individual tests. The former are intended to be trials of short duration of a number of machines performing the same operation, reports on the results to be published for general information. The individual tests are suggested to enable farmers and others to obtain an idea of the performance of a machine. A certificate would be granted stating that the machine had done a specified amount of work at a certain cost, and recording its state at the end of the trial, merits as regards accessibility, replaceability of parts, wear and so on. Further, research work on the exact requirements to be met in the design of machines, and the promotion of discussion and exchange of views between all interested, as well as the encouragement of improved or new appliances, are to form part of the scheme. In all these matters we believe representatives of the Institution of Mechanical Engineers would be able to make contributions of the greatest value.

It is to be noted that the report is against direct assistance to inventors, and in this we concur. The matter has been raised by the Institute of Patentees approaching the Ministry with a proposal that prizes should be offered for improved designs of agricultural machinery. We are afraid that the State at the moment has quite enough things on which to spend its money, without embarking upon such a scheme. Actually the Ministry of Agriculture has rendered assistance in the case of some new ideas put forward, and we believe has brought their introducers into touch with manufacturers with satisfactory results. The Institute of Patentees itself is, however, an independent body, mainly formed we understand for the purpose of assisting or discouraging inventors, as the case may be, and it is therefore hardly necessary to add to the work of State departments by expecting them to nurse inventions through the ailments of

childhood. The work of this Institute has been countenanced by the Board of Trade, and it is very appropriately subsidised by the Charity Commissioners, from which we may hope that petitioners for assistance are kindly dealt with.

THE COST OF ADMIRALTY.

THE man in the street is interested only in the aggregate amounts which the various Departments of State estimate they will require for their particular purposes from year to year, and their relation to the amounts required for the same purposes in the preceding year. So long as the sum required shows a decrease he is contented, and for this reason a reduction in the Navy Estimates for 1923–24 by nearly seven millions from that of 1922–23 is naturally a source of much satisfaction to him.

A more limited number are interested in a comparison of the different and numerous main groups into which the whole Vote is for convenience divided, and it was probably one of these who recently asked in Parliament for an explanation of the large increase in the sum required for the Admiralty Office for 1923–24 as compared with the corresponding amount for 1914–15. A very much smaller number concern themselves with a detailed examination of the subheads into which the main groups of the Vote are divided, and find much food for thought, and probably for Parliamentary questions, in comparison of those with similar details for other years. The member of Parliament for a dockyard town, for instance, will study and compare the sum allowed for labour in the dockyard of that town, for he is fully aware that local bodies will urge him to plead their case with the responsible authorities if the amount allowed is less than in previous years, and indicative of a diminution in the number of persons employed. Private firms on the other hand are concerned in the amounts which are allocated under various votes likely to give their employees work. Others may be interested in the victualling vote, their particular concern being in the direction of ensuring that good and sufficient food and clothing are supplied to our seamen.

So by various interests different subheads are studied, and comparisons and deductions made for the particular purpose for which they are required. It is possible one or two diligent and ingenious inquirers will dissect and compare the details of the whole of the 58 million of the Navy Estimates, only to find when his self-imposed task is completed that the estimates for the following year are ready for his examination.

The question asked by the member of Parliament as to the cost of the Admiralty Office prompted an examination of the details of numbers and costs for the purpose of comparing these with the corresponding details of the estimates ten years ago. At the outset it may be stated the Navy Estimates for 1913–14 totalled 46 million pounds, compared with 58 millions for the present year, of these amounts the Admiralty Office required 450 and 1,200 thousands, respectively. As a percentage of the whole vote the cost has increased from just under one to two.

An examination of the different groups into which Vote 12—Admiralty Office—is divided shows that various new departments have been formed in the past ten years. Thus the Ordnance Department in 1913–14 was responsible for guns, torpedoes, mines and signals, whereas in the present year these matters are dealt with directly by at least five departments, each with its own director, assistant directors and appropriate staffs. The Secretary's Department is also divided into two as compared with one in 1913–14, one section dealing with purely secretarial work and the other with records, registration and copying. On the other hand a few departments, Transport, Air and Compass, which in 1913–14 were allotted a sum of 17,000*l.*, have disappeared from the vote for the Admiralty office.

A further examination of the details of the various departments shows these can be divided into four main groups depending upon the composition or duties of the personnel. The first group is almost wholly naval, *i.e.*, composed of naval officers; the second group is partly naval and partly civilian, the former holding the whole of the superior appointments, the civilians being all subordinate; the third group is wholly civilian and technical; and the last group is wholly civilian and clerical. In the following table this grouping is adopted, the sums allocated in the estimates for the two years for which the comparison is made, being expressed in hundreds of pounds and the percentages to the nearest 10. The numbers and sums required for domestic purposes, *i.e.*, office keepers, &c., are shown separately. Various minor details are omitted as they have little effect on the comparison.

TABLE.

	1923–24.		1913–14.		Increase per Cent.	
	Numbers.	Cost in Hundreds.	Numbers.	Cost in Hundreds.	Numbers.	Cost.
Group I.						
Board of Admiralty ..	11	256	10	197	10	30
Naval assistants	15	163	5	41	200	300
Naval staff	135	1,022	51	239	160	330
Naval attachés ..	14	216	7	56	100	280
Naval Equipment Department ..	12	116	7	38	70	200
Naval Reserve Department	11	94	17	70	−35	30
Physical Training Department	2	29	—	—	—	—
Medical Department ..	28	178	24	96	17	85
Naval Personnel Department	2	21	—	—	—	—
Chaplain of Fleet ..	2	22	2	14	0	60
Wireless Telegraphy Board	3	16	—	—	—	—
Totals	235	2,133	123	751	90	180
Group II.						
Naval Engineering Department ..	62	420	52	188	20	120
Armament Department	261	1,366	109	336	140	300
Totals	323	1,786	161	524	100	240
Group III.						
Naval Construction Department ..	182	850	186	520	nil	60
Civil Engineering Department	132	657	130	350	nil	90
Electrical Engineering Department ..	32	352	23	70	260	400
Dockyard Department	68	363	35	125	90	13
Totals	464	2,222	374	1,065	20	110
Group IV.						
Account-General Department	665	2,219	347	735	90	200
Secretary's Department	138	736	116	352	20	110
Record, &c., Department	250	505	—	—	—	—
Naval Store Department	149	613	84	213	80	190
Contract Department	164	663	95	248	70	160
Dockyard Expense Department ..	38	140	21	53	80	160
Victualling Department	55	218	40	112	40	90
Temporary clerks ..	469	607	—	40	—	1,420
Totals	1,928	5,701	703	1,753	170	220
Office-keepers, &c. ..	461	617	322	187	40	230
Grand total	3,411	12,459	1,683	4,280	100	190

Included in the amounts given in column 3 are the following sums paid as bonus to the civilian members of the staff: Group I, 10,700*l.*; II, 28,800*l.*; III, 64,600*l.*; IV, 167,200*l.*; office-keepers, 21,600*l.* A total of 293,000*l.*, which will gradually disappear as the cost of living decreases. Further than this, the temporary staff will no doubt diminish as the liquidation of war work is completed, and this will result in a further reduction of about 60,000*l.* The effect of these two temporary increases is to reduce the cost by 350,000*l.*, leaving the normal cost about 900,000*l.*, an increase of 110 per cent. on that for 1913–14.

A comparison of the grand totals given in the table shows that in ten years the numbers employed have been just doubled and the cost increased very nearly three times. This general remark also applies to the totals of Groups I, II and IV, but in Group III the numbers have only increased by 20 per cent. and cost by 110 per cent. The numbers of Group I are almost exactly one-half of those of Group III, while the costs are nearly the same.

According to the details of Group I the greatest increase is in the naval staff, which, with an addition of 160 per cent. in numbers involved an extra cost of 330. The difference in cost is no doubt partly due to the higher emoluments given to naval officers after the war. The same reason holds for the increases of Group II, for which an addition of 100 per cent. in numbers is accompanied by one of 240 per cent. in cost.

The cost per unit of staff varies with the different groups, and for details of each. For Group I this has increased from 610*l.* to 910*l.*; II, 325*l.* to 550*l.*; III, 285*l.* to 480*l.*; and IV, 250*l.* to 300*l.* In these figures the influence of the increased naval pay is again apparent. It is also to be noticed that the withdrawal of the bonus will affect Groups I and II to a much smaller degree than Groups III and IV, and the increases in cost per unit for the two latter groups will be decreased.

Referring to the details of Groups II, III and IV, the greatest increases in each is in the Naval Engineering Department, where the cost per unit has risen from 360*l.* to 665*l.*; Civil Engineering, from 270*l.* to 500*l.*; and Secretary's Department, 300*l.* to 530*l.* The three other Engineering Departments of Group III give increases of 280*l.* to 470*l.* for the Construction Department, 300*l.* to 430*l.* for Electrical Engineering, and 360*l.* to 530*l.* for the Dockyard Department.

The highest cost per unit, excluding the Board of Admiralty, is that of the naval assistants, nearly 1,100*l.*, followed by naval equipment 960*l.*, naval staff 760*l.*, naval engineering 680*l.*, medical 630*l.*, dockyard 530*l.*, armament, 520*l.*, civil engineering 500*l.*, naval construction 470*l.*, and electrical engineering 430*l.* Of the purely clerical departments the similar figures are secretary's 530*l.*, naval stores 410*l.*, contract and victualling each 400*l.*, accountant-generals 330*l.* and records 200*l.*

Of the total numbers in each department, all have increased except three, the Naval Reserve, Naval Construction and Civil Engineering. The decrease in the first is no doubt due to the abolition of the Coast Guard which, according to the 1913–14 Estimates came under the directions of this department. The greatest increase, except in the temporary clerks, is in electrical engineering, whose numbers have increased 260 per cent., an indication of the growth of the use in electrical appliances in the Fleet during ten years.

For the clerical departments the increases in numbers vary from 20 per cent. to 90 per cent. although if the Secretary's and Record Departments are grouped together as in 1913–14 the increase is 230 per cent. Of the 469 temporary clerks 331 are attached to the accountant-general and 84 to the Record Department, which raises the increases in numbers in these two to 190 per cent. and 300 per cent.

To the ordinary observer it might have been expected as a general rule that increase in one department of an office, such as the Admiralty which deals with one particular business only, would be followed by similar increases in the others. The percentage increases are, however, most irregular, and although in a few instances abnormal increases can be explained by extensive developments in the particular branch considered, yet this cannot apply to the greater number. Probably a much more minute examination and comparison would give some explanation of these differences, but with the lack of opportunity to do this the matter must be left to speculation.

STUDIES OF A WIRELESS LABORATORY.

THE possibilities of radio-telegraphy, tested in the laboratory though not yet tried on a large scale, which Dr. W. H. Eccles, F.R.S., Dean of the City and Guild's Technical Institute, Finsbury, demonstrated at the Royal Institution on Friday, the 13th inst., would be of interest, even if in radio-telegraphy the possibilities of to-day did not become the actualities of to-morrow. The discourse was on the utilisation of forced vibrations.

If a simple string and bob pendulum, of a period of two seconds, Dr. Eccles explained, were held by hand, and the hand were moved horizontally to and fro with a periodic motion of one second (or of three seconds), the pendulum would acquire the rate of vibration of the hand and would vibrate once (or three times) per second, "in time, though not in step" with the hand. The hand and pendulum would not be in tune, but in an "accordant state," like the fore legs and hind legs of a running

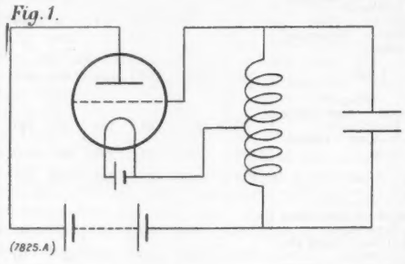
dog. The pendulum vibrations would be damped. In wireless telegraphy undamped waves of higher frequency were used. To exemplify cases of a few hundred oscillations per second, Dr. Eccles used a peculiar pendulum and a diode (two-electrode valve). The pendulum of T shape, was a horizontal bar magnet to which a rod of ebonite was attached; the bar poles faced two solenoids, and this system was suspended by a torsion wire. The two solenoids were connected in series to the diode and a battery. The electronic current in a diode valve was affected by external electric influences; when therefore the ebonite was electrified by friction and the pendulum was set vibrating, so as to approach the valve and to recede from it again, the diode currents and hence the solenoid currents were alternately weakened and strengthened by the positive electrification of the ebonite, and the pendulum motion was thus sustained. These oscillations were indicated by a light spot reflected from a small mirror attached to the bar. Using now two such pendulums of different periods the one could be made the "master" by sending part of its current through an auxiliary winding, and the frequency of either master or "servant" could be varied by bringing a permanent magnet near the oscillating magnet. When this was done and the two light spots (moving to and fro on a scale) were watched, it was seen that the servant would be compelled to move in time with the master—not necessarily in step again, though that could be adjusted.

To demonstrate the same effect for ordinary acoustical oscillations (about 200 per second), Dr. Eccles made use of a triode (three-electrode valve) and a tuning fork, the prongs of which vibrated between the poles of coils and poles of solenoids in circuit with the grid; that arrangement was a good master. A good servant was made by an electric oscillator (without magnets) as in Fig. 1. The linkage between the two oscillations was affected by passing some of the current from the fork coils through an auxiliary winding of the electric oscillator. The vibrating fork was audible; the electric oscillations were inaudible, but could be made audible with the aid of a telephone shunt, the note of which was changed by slowly varying the capacity of the condenser by means of a tuning handle. As this was done and the frequency of the oscillator approached that of the fork, "beats" were heard, until suddenly the master dragged the servant into time, when the throbbings ceased. When the movement of the handle was still continued, master and servant kept in resonance over a small range; then the servant broke away again, and the beats were once more heard. That experiment was the analogue of what Rayleigh showed in 1879, namely, that two organ pipes, nearly in unison, dragged one another into common frequency when brought into propinquity.

Passing to the inaudible high-frequency oscillations (of the order of 200,000), Dr. Eccles used a similar oscillator and a detecting device consisting of an inductance, a coil, a variable condenser and a crystal connected to a galvanometer. The galvanometer would show a maximum deflection when the receiver was in tune with the oscillator. A second oscillator was then joined to the same detector and tuned; the two oscillators were then of about the same frequency. They were next made to act simultaneously upon the detector, and further, a pair of auxiliary coils (in series) was approached to the two oscillators to establish a linkage between them. By gradually moving the tuning handle of the condenser of one oscillator, the galvanometer deflections were slowly increased; as the handle was turned further, the deflections would suddenly drop and then increase again in a V curve (Fig. 2). The frequency and the pitch of the note heard in the telephone changed at the same time; that is to say, the sound increased, ceased during the resonance period, and was heard again. At the lowest point of the V the two oscillators would vibrate in time, but in opposite sense. That observation was due to Dr. J. H. Vincent and could be utilised in various ways. Suppose one oscillator to be a distant station, and its wave be picked up by an antenna coupled to a local oscillator in the relationship as master, the tuned detecting circuit being acted upon by both the antenna and the local oscillator; with the local oscillator adjusted until it was in accordant state with the antenna oscillators and the detector at the minimum of the V curve, a very minute variation in the frequency oscillation of the distant station would give rise to a galvanometer deflection. Thus signals could be transmitted by frequency changes (up and down) far smaller than those in use, and the interference between stations could be minimised. The adjustment could also be effected by approaching a small movable coil to the inductance of the transmitter, and the galvanometer scale could be marked in the letters of the alphabet for communication without the aid of Morse codes.

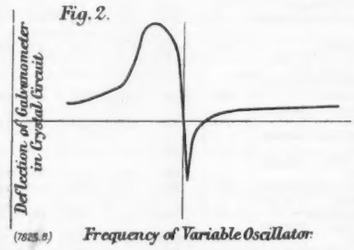
Other new methods depended upon the interference of two high frequencies. In the ordinary heterodyne method receiver and transmitter were not tuned to the same frequency: if they differed, *e.g.*, by 200 oscillations, the operator heard that note in the telephone, and when the trains of waves were broken up to Morse code, signals of pitch 200 were heard. Now, suggested Dr. Eccles, let the transmitter send 200,000 oscillations to represent dots and 199,800 to represent dashes; add at the receiving station frequency 200,200; then the receiver would hear telephone notes 200 instead of dots and notes 400 for dashes, and these notes would suffer less from atmospheric interference

Fig. 1.



(7825.A)

Fig. 2.



(7825.B) *Frequency of Variable Oscillator.*

than ordinary signals. Or use frequency 200,100 for dots, 200,200 for dashes and 200,050 for spacing; add at the receiving station frequency 200,200; then frequencies 50, 100, 200 would signify space, dot, dash—a more complicated, but more readily recognisable system.

Another method again, that of sending chords, was based upon the quite recent acoustical experiments of Sir R. A. Paget. According to Paget, each vowel could be produced by passing a larynx note through a pair of suitable resonators formed as in the uval cavity; a larynx could be supplied by a buzzer, say of frequency 100. To produce, for example, the sound of the long *e* required two simultaneous sounds of 2434 and 322 vibrations respectively. Dr. Eccles sent vibrations of 202,434 and 200,322 vibrations respectively through two oscillators and received them by a detecting circuit of 200,000; then the long *e* sound was heard. Similarly he produced with the aid of coils and variable inductances, controlled by six keys, sounds corresponding to short *e*, to *a* (Continental), *o*, *u* and *ur* (in hurdle). Now if the long *e* were represented by a vertical line, *a* by a horizontal line, *o* by a full circle, short *e* by the left half of a circle, *u* by a U and *ur* by an inverted U, those symbols might be used to make up vowels and also consonants in Roman type. Thus the letter L could be represented by the two symbols *e*, *a* (vertical and horizontal line), the two vowels being sent in quick succession; the letter *d* by the symbols *o*, *e*; *ur* might stand for the consonant *n*, and so the word London was spelt out by vowel sounds. By these means words could be sent with a very much reduced number of efforts represented by key operations in Morse signalling.

TRAFFIC ACCIDENTS.

IN this country the publication of facts and figures is a device often resorted to, to place people or concerns under the moral obligation of mending their ways. We probably rely upon the real or imaginary compelling force thus indirectly invoked to a greater extent than any other nation, and we flatter ourselves that our consciences are on the whole tender enough for the system to work better with us than would one founded upon the bureaucratic regulation common in Continental countries. A notable instance of the practice has been the system of investigating railway accidents, and publishing official reports thereon with "recommendations," without, however, power to enforce the latter. It is typical of the attitude of the railways to the general question of making their services meet with the approval of their patrons, that these recommendations are very generally adopted. It sometimes happens, of course, that they cover matters of principle rather than detail, and when this is so, and the effect of a fundamental departure from existing practice would be far-reaching and expensive to bring about, any change must almost of necessity become one of evolution instead of conversion. The effect of the influence at work then takes some time to become evident, and the companies are subjected to obloquy in an uninformed section of the Press as being unprogressive and callous.

Another point which tends to influence the public adversely against the railways is the manner in which accident returns are published. Primarily these figures should be as instructive as it is possible to make them, but they cannot be said to approach this ideal in any sense. Originally, we take it, the idea was, in the days when railways were looked upon as the friends of nobody but themselves, to bring public pressure to bear upon them to do everything possible to reduce the loss of life caused by their operation. The official statistics were made to include every casualty at all serious occurring on railway premises. They do so still, and frequently these gross figures are quoted by the casual disputant at home, or by the foreigner who has only condensed summaries of the statistics to work upon. The natural result is that the railways come under an undeserved stigma, since in the casualty list suicides are given the same evaluation as passengers in a train accident, or an injury to a horse driver due to a fall from the seat of his cart, is rated similarly to the case of a man disabled through careless shunting. The lists cover all cases, and many of them are such as would be liable to occur on any factory or other premises where it is the practice to handle goods, and are not peculiar to railway methods. Again, many are due to want of caution on the part of the public. Nearly half the figures recorded relate to casualties occurring to persons entering or leaving trains, falling out of carriages and falling from platforms. These are mainly due to carelessness on the part of the injured persons. All this brings us to the point that to be of the most service according to modern ideas these figures require some re-classification. Some might even be eliminated from the railway statistics altogether, or be included as in connection with work ancillary only to transport.

We have to-day got beyond the idea that the issue of these statistics of itself will keep down the number of accidents. The safety campaign has, in recent years, been placed upon a new footing. What we want to know now is where the blame lies so that intelligent steps may be taken to prevent casualties. For years the railways have had warning boards against trespassing, and the general influence of education has been set against suicide, yet these figures in the railway casualty list only show a relatively small diminution. The railways have done a good deal in the way of training their men in safety habits, but it is improbable that anything will ever prevent belated persons rushing violently down stairs to catch a moving train. The public needs as much instruction in these matters as the railways, and more might be done in this direction.

The London Electric Railways have for some time carried on an instructive campaign of this kind, not always perhaps with happy results, but the intention is commendable and might be followed more widely. It is quite certain that if it were possible to imbue the public with greater caution the so-called railway accident figures would be greatly reduced, and if we could have statistics which classified casualties so that they could be used instructively in this way it would be to the general advantage.

With 'bus traffic the general risk of accidents is greater, but as Mr. H. E. Blain showed in his lecture to the graduates of the Institute of Transport last week, much is being done to improve this so far as the transport companies are concerned. Both in railway work and in the omnibus business appliances of various kinds are being introduced to make the movement of vehicles safer, and inducements are held out to the drivers of 'buses to develop a high degree of skill and care in working. We are glad to think that figures show that the men are responding excellently to these efforts. The public is harder to influence and slower to learn, but we believe it would assist in reducing the casualties if more publicity could be given to acts of carelessness, which, generally speaking, we are satisfied to dismiss lightly with a reference to the tempting of providence.

TRANSMISSION OF SPEECH BY LIGHT.

TRANSMISSION of sound by light or photophony, though practically as old as transmission of sound by electricity—electric telephony—yet retains its novelty. This fact implies a comparatively slow development. That the photophone has not successfully rivalled the telephone and radiotelephone is hardly surprising. Graham Bell's telephone of 1875 found the electric telegraph with its instruments and lines securely established; the telephone development was a natural parallel growth, while radiotelegraphy quickly overcame the distance-limitations of optical telegraphy. Bell, however, spoke over a distance of 700 ft. by means of his photophone in 1880; the photophone of Ernst Ruhmer, 1890, carried speech 5 miles; and during the war scientists in all countries resumed photophone researches with more or less success. That these achievements have remained sporadic, Professor A. O. Rankine, D.Sc., of South Kensington, one of those war-workers, lecturing at the Royal Institution on April 12 and 19, ascribed largely to the capriciousness of selenium. "Transmission of Speech by Light," he stated, still depended on selenium though he would gladly abandon selenium in favour of a superior substitute.

The transmission of speech by light is effected by modulating the intensity of a beam of light by means of the acoustical vibrations. In the distance the fluctuating beam falls upon the receiver, a selenium cell in circuit with a battery and telephone; the selenium can control the current because it is a better conductor of electricity when illuminated than when in darkness; thus the brightness of the light and the telephone current vary in correspondence with the speech vibrations. Dr. Rankine, in his lecture, first described the receiver. He makes use of the selenium cells of Professor H. Thirring, of Vienna.

Two electrode combs of fine copper foil are pushed into one another as shown in Fig. 1, and separated by plates of mica forming a surface consisting of alternating edges of copper and mica, the latter not coming quite flush with the copper. Over the surface is placed a disc of selenium, only 0·01 mm. thick, and a few millimetres in diameter; the selenium thus bridges the gaps between adjacent copper electrodes. By moving a cell of the shape of a vertical rod along an arc spectrum, Dr. Rankine showed that the maximum sensitiveness of selenium to light lies in the red. In the ideal cell the current should, on illumination, at once rise to a maximum and drop off completely when the light is cut off; unfortunately there is a lag, especially in the return, and temperature and battery current also affect the resistance, selenium being very capricious. Yet selenium responds sufficiently well to light fluctuations for the purpose, better perhaps than the very sensitive "thalofide" cells of T. W. Case, of New York, said to consist of a compound of thallium, sulphur and oxygen spread on quartz. The mere uncovering of a thalofide cell in the completely darkened lecture room, Dr. Rankine demonstrated, gave a strong galvanometer deflection.

The acoustic modulations may be impressed on the beam in two ways. Either the speech can be made to directly vary the intensity of the source of light, or it can modify the beam intensity, leaving the source constant. The latter method is preferable, partly because it makes the Sun available as light source. Graham Bell tried or proposed shutter and grid arrangements, and later a mirror diaphragm; Ruhmer used the singing arc of Simon and Duddell, but seems to have found the maintenance of the proper arc conditions difficult, for later he applied his method mainly to the study of the peculiarities of the electric arc. Dr. Rankine's arrangement is illustrated in Fig. 2. The speaker talks into a horn closed by a mica diaphragm against the centre of which a lever bears. To a short arm of this lever a small mirror (galvanometer mirror, 1 cm. in diameter) is so attached that it will oscillate about its vertical axis when the diaphragm vibrates. The mirror is slightly concave, the radius of curvature being 1 m., the distance from the two lenses shown. The light of a Pointolite lamp is concentrated by one lens upon the mirror, and is

Fig.1.

Fig.2. DIAGRAM OF TRANSMITTER, SHOWING PRODUCTION OF FLUCTUATING BEAM.

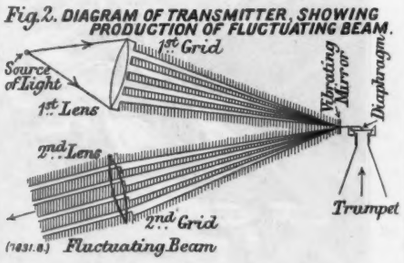
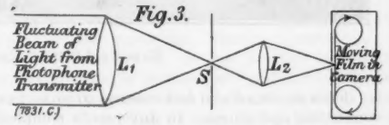


Fig.3.



reflected by the mirror back to the other lens and passes through that lens to the selenium receiver in the distance. Each lens, about 15 cm. (6 in.) diameter, is plano-convex and is covered, on the mirror side, by a metal grid of vertical bars, about 2 mm. (0·1 in.) wide and apart. This combination of movable mirror and stationary grids is far superior to any mechanical shutter diaphragms. The first grid slices the incident beam up vertically. When the mirror is at rest, the reflected slices will again so be focussed on the second grid that the light can pass unobstructed. When the oscillating mirror is turned to the right or left, all the slices will be deflected and part of a beam slice (half in Fig. 2) will hit a bar on the second grid, and will not pass through the second lens. Thus the light beam travelling on to the receiver, though no longer of grid structure, will fluctuate in intensity in accord with the acoustical vibrations. The concavity of the mirror is essential to secure fair focussing. Graham Bell had spoken of a plane mirror diaphragm though he probably used—if he tried it at all—a curved mirror; the to-and-fro' oscillations of a plane mirror would make focussing impossible.

In his demonstration, Dr. Rankine had placed his apparatus outside the lecture room, while the beam leaving the second lens and suitably reflected by a plane mirror, entered through a hole in the wall to strike the receiver. The sounds, magnified by a thermionic valve, were clearly heard, but not when a sheet of paper was interposed in the light beam; speaking too loud was as inadvisable as in telephony.

By the arrangement shown in Fig. 3 photographic records are obtained. The fluctuating beam from the transmitter is concentrated by the lens L_1 on the horizontal narrow slit S, and an image of this slit is thrown by L_2 on the moving film of a camera, running upward at a speed of more than 1 m. per second. Tuning forks, musical notes, vowels, spoken words, &c., then give records resembling fluted spectra, consisting of a series of lighter and darker bands. The intensity fluctuations in the light correspond to the longitudinal displacements and the waves of condensation and rarefaction travelling through the air. These films, Dr. Rankine further demonstrated, can be used to reproduce the original sounds. The arrangement of parts for this purpose was: Arc, lens, slit, lens, moving film, selenium cell. The light falling on a dark band would be obstructed by the silver deposit on the film, a light band allowing the light to pass through. For the demonstration, Dr. Rankine took a film—a negative—on which the word "bought" had been continuously recorded. The film was mounted like a belt on two pulleys and was turned by hand at different rates; the word came out in high or low notes, according to the rate of turning, very distinctly. Dr. Rankine had first used very narrow slits, of less than 0·2 mm. width, for making his films and for the sound reproduction; but he found that the slit width and the film speed could be varied within wide limits, and examination of his films further proved that records of the same word may differ considerably—we do not always speak in the same way—and the sound reproduction will yet be successful.

It will be understood that these records of longitudinal wave displacements are different from the records of acoustical wave amplitudes. Dr. Rankine also exhibited such records obtained with the aid of the sonometer or audiometer of Mr. F. Twyman and Messrs. Adam Hilger. In the audiometer the speaker talks into a horn closed by a diaphragm which is silvered or gilt in the centre, and the light beam from a lamp is reflected on to the moving film. With the new Hilger celluloid films,* of the thickness of a wave-length, very remarkable curves of sounds and spoken words are obtained.

In his conclusion, Dr. Rankine drew attention to the analogy between telephony by light and radiotelephony. The carrier-waves are of the same type in the two cases, but they differ greatly in length; light waves are of the order of a few microns (ten thousandths of a millimetre), radiotelegraphy waves of the order of a kilometre. That difference enables the photophone to be worked with a single directed beam of light, without any need of tuning and free from interferences; on the other hand, direction of radiotelegraphy is still difficult, but broadcasting can be effected in all directions from a single transmitter. Further, radio-signals travel all round the world, photophone signals are restricted to rectilinear paths. As regards the applications of the photophone it is noteworthy that it makes a superior microphone and is actually being used in the Manchester broadcasting station for the purpose of modulating the carrier wave. The sequence of events then is curiously long and interesting. The singing performer sets air in vibration, the vibrations impinge on a diaphragm displacing it by perhaps $\frac{1}{1,000}$ in.; a mirror on the diaphragm sends fluctuating light waves to a selenium cell which—itself, behaving like a valve opened and closed by light—imparts equivalent fluctuations to an electric current; these fluctuations are amplified several times by thermoionic valves, eventually to modify the radiofrequency in the transmitting valve. The modulated carrier waves pass through the ether, to a crystal detector, more amplifiers and finally to a telephone. It is indeed remarkable that after all these transformations the reproduced sounds bear so close a resemblance to the original sounds. For long-range photo-telephones, *e.g.*, between ships and shore and distant stations, sunlight or powerful arcs are required. Good articulation can certainly be obtained with apparatus of this kind.

*See ENGINEERING January 12, page 37 *ante*.

SHIP SALVAGE OPERATIONS.

By DUDLEY E. J. OFFORD, R.C.N.C.

IT is most probable that the first ship salvage operation was taken in hand very shortly after the first ship was launched, and therefore even a most scanty review of the history of our subject would prove a colossal task. It is, however, only within the last twenty or thirty years that the subject has received any real scientific significance, and one can safely assert that the progress made during this period has been phenomenal, and ship salvage can now claim to be one of the scientific branches of practical engineering.

Of all modern inventions the petrol engine is undoubtedly the most important from the ship salvor's point of view, and its development into a reliable power producer has solved many of his worst problems and placed into his hands a machine which is extremely light, readily portable, and which in combination with air compressors, centrifugal pumps and dynamos can claim to have supplied the majority of his wants. Next in importance is probably the development of satisfactory submersible electric centrifugal pumps, which can be readily driven from an electric alternator and petrol engine. Formerly, it was necessary to employ steam-driven machinery, which was in itself heavy, and also involved the provision of considerable boiler power and its consequent weight. Moreover, there was the disadvantage of hot steam pipes lying about the wreck, radiation and leakage losses were enormous, much valuable time was wasted in warming up the engines and priming the pumps, whilst the exhaust steam caused great inconvenience to men working in the vicinity. The provision of fresh water and coal for the boilers was in itself no mean problem. Happily, these days are past, and a modern salvage equipment is entirely free from steam driven auxiliaries.

Pneumatic tools, such as hammers, chippers and drills, adapted for under-water use, have also rendered most operations capable of execution in a mere fraction of the time formerly found necessary; whilst in the last year or so much thought and attention has been given to the development of under-water oxy-acetylene burners. These have already reached a stage where in the hands of an experienced diver, they can be profitably and usefully employed for the work of cutting away small portions of structure preparatory to patching, and after the main portion of the damaged plating, &c., has been removed by gelignite or some other suitable blasting agent.

The telephone, too, has been successfully introduced as a useful adjunct to the diver's outfit, and enables reports to be made and instructions to be given without the loss of time formerly involved in coming to the surface. This factor is of far greater importance than would appear at first, for it must be remembered that when working at any appreciable depth the diver must ascend and descend very slowly, so that his system can gradually become adapted to the varying pressure conditions. If this is not done serious illness, or even death may result.

A properly-fitted salvage steamer should carry an extensive outfit of the plant referred to together with a good supply of hemp and wire ropes, various sizes of deals and planking, shores, wedges, &c., cement, oakum, canvas, hook and tumbler bolts, hoses, electric cables, &c. The ship should be fitted with strong derricks and winches both forward and aft, and should also have ample engine power and be fitted for towing. She must of necessity be a good sea boat, strongly constructed to withstand bumping against the wreck, or even grounding at low tide, and should carry a good supply of stout fenders for her own protection. Accommodation for divers, mechanics, &c., should be provided to the maximum extent, but in any case she should have ample cooking arrangements to provide a good supply of hot food for the persons engaged on the work. It is, therefore, apparent that the requirements are many and that the equipment to be carried is extensive, but on the other hand the dimensions of the vessel must not be too large, otherwise she may not be able to reach, or lie alongside the wreck, and it is moreover essential that she may be easily handled. All these points require attention.

The above is intended only as a brief indication, and is by no means a comprehensive survey of the plant and equipment which should be available for a successful operation of a general nature. It is sufficient, however, to indicate that a great deal of capital is involved in its supply and it is, therefore, not surprising that during the war, when due to enemy action wrecks were unfortunately of frequent occurrence, the Admiralty found it necessary to form its own salvage section and to provide its equipment. Certain equipment was already available in the country, and of course this was utilised to the fullest possible extent.

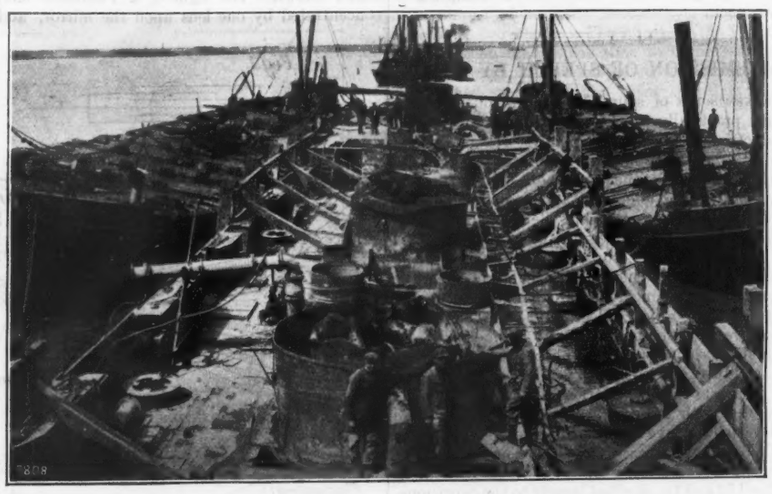
Having provided himself with a complete, up-to-date, and efficient equipment the ship salvor must rely on his own initiative and luck for the complete success in his operations. "Luck" has been included not from any particular desire to make an acknowledgment of the seaman's alleged superstitions, but because, until meteorological science can accurately predict weather not only days but months in advance, work which has taken months to perform and on which the greatest possible care and skill has been brought to bear, may be completely vitiated by a few hours of boisterous weather.

In so far as no two ships which founder or run aground receive identical damage, it is not possible to lay down any hard and fast rules as to procedure in conducting operations. In any case a complete survey of the wreck is the first thing to be done, and in this connection an experienced and skilled diver is almost invaluable. He knows what to look for and how to make his report so as to convey to the person in charge an accurate impression of the state of the wreck. Plans of the vessel, charts of the vicinity, and all information as to tides, weather, &c., peculiar to the particular district should be obtained, and all carefully studied and analysed preparatory to the formulation of the plan of campaign.

The salvage operations may be desired either to recover the vessel, or to remove her from a position in which she is a danger or a hindrance to navigation. In the former case, finance is of great importance, for the cost of salvage and reconditioning the vessel after salvage, must both be estimated to ensure that in comparison with the value of the vessel when reconditioned, the transaction will prove a commercial success. In the latter case, however, it often happens that the vessel must be moved at all cost, and then the money problem is less acute, and the principal consideration is to carry out the work as cheaply and expeditiously as possible.

The flotation of the vessel may be obtained either by recovering sufficient buoyancy within the vessel herself, or by the application of external lifting forces, or, of course, by a combination of both. As regards recovering buoyancy it is essential to first of all locate the damage, and if possible, to patch it over. This patching is usually done with timber, the joints on the ship's plating being rendered watertight by fitting canvas bolsters filled with oakum. The method of securing the planking of course depends on the conditions at the ship, but long hook-shaped bolts with butterfly nuts are generally most efficient. The hook portion can be attached to frames, or plate edges, and the butterfly nut is most readily dealt with by a diver, the usual hexagon nut which calls for the use of a spanner proving rather difficult to handle. The wood sections require to be weighted so that they are not buoyant, and so that the diver can handle them when under water. Old fire-bars, a supply of which is usually available, are very suitable for this purpose. It is surprising how efficient a patch a skilled diver can erect and fit in a few working hours. If the damage is not extensive and is situated in a central position on the ship it is often possible for the carpenters to make a complete patch above water, when the diver has only to secure it in place.

All minor sources of leakage such as port holes, ventilation trunks, hatches, &c., must receive attention and suitable means devised for their closure. Sawdust has been found to be an effective agent for stopping small leakages through edges and butts, cracks, unsound rivets, &c. The flow of water through these leaks during pumping operations draws the sawdust into them, where it becomes lodged, very soon swells and so closes the orifice.



BARGES LIFTING ZEEBRUGGE BLOCK-SHIPS.

Having closed all the holes it is a comparatively easy matter to pump out the wreck, and of course, provided sufficient buoyancy has been recovered, the ship will float. In this connection one must, of course, pay great attention to the trim and stability of the vessel, not only in her final condition, but in all intermediate stages, to ensure that she will not take up a dangerous position, or one that will cause damage to the attending craft. As the pumping proceeds, and as soon as the main patch or patches are subject to the varying water pressure, it is often necessary, and in any case usually desirable, to shore them from within the vessel and possibly to tighten, or readjust some of the hook or tumbler bolts.

If the damage or aperture is fairly low down in the ship, and conditions are otherwise favourable, it is often preferable to gain buoyancy by expelling the water by means of compressed air. When damage is in the bottom of a vessel, the fracture is often inaccessible and then the compressed air method is the most practicable one available. The deck, or upper portion of the compartment, has to be rendered airtight before the operation can be carried out and cement has been found most useful in this respect. Concrete is not sufficiently airtight unless large quantities are used, and it is usually an ultimate economy to use pure, quick-setting cement. If large areas are affected the surface of the cement should be criss-crossed with planks and these effectively shored down before the cement has finally set. Several days should elapse before air pressure is applied, and a breathing pipe should be fitted to allow the free ingress and egress of the water with the rise and fall of tide, so as not to strain the cement and

structure until such time as it is desired to apply the pressure. The air supply pipe should be of ample size and one, or more pressure gauges should be connected to the top of the compartment and placed in a position where they can be readily seen during lifting. The gauges should have large clear dials with graduations such that the pressure can be read to at least ¼ lb. per square inch.

For the application of lifting forces by external agencies many ingenious devices have been proposed from time to time, but it is found that under conditions usually existing the following method is the best. The size and distribution of the gear will, of course, vary with the force required, and the length and size of the vessel, but to illustrate the principal we will assume the vessel to be a cargo ship of medium size and weight. Steel wire hawsers are used for lifting, and it has been found that these cannot be satisfactorily attached to the ship's structure. It is usual, therefore, to make a cradle of these wires in which the ship is eventually suspended. If the wreck is lying lightly on a sandy, or light mud bottom, a sweeping wire is first placed under her bow and the two ends led to powerful tugs. These steam off so that the wires lie at an angle of about 30 deg. to the fore and aft line of the wreck and then by alternately towing and backing, the wire is see-sawed under the wreck. When the sweeping wire is thus brought to the position required for the lifting wire it is used as a messenger, the lifting wire, which is usually about a 9-in. special flexible wire hawser, is bent on and by means of winches pulled round under the wreck. The lifting wires are placed under the wreck in pairs, and by a repetition of the process all the wires required can be got into position. Eight such pairs of wires would be a usual number, and as far as possible they should be positioned to come on the frames of the wreck.

If the wreck is deeply embedded in the mud, or if the vessel is in a congested position the sweeping method described above may not be possible. It has been found that divers working with a powerful high-pressure water hydrant can, with comparative ease, cut a tunnel under the wreck, and through this the wires can be passed. A centrifugal pump, or a compressed air ejector should be used in conjunction with the hydrant to carry off the mud, after it has been cut away by the latter. The "block ships" at Zeebrugge were embedded 10 ft. or 12 ft. in hard mud, but by means of this method tunnels were cut under them in a few weeks, and no less than 14 pairs of wires placed under each ship.

The wires when in place have their ends tied up in the proper pairs on the deck of the wreck, or else securely buoyed and labelled for identification purposes. When this operation and any other preparatory work is complete, the lifting barges are brought into position on each side of the wreck. One wire of a pair has its starboard end brought over the outer side of the starboard barge, and its port end brought up on the inner side of the port barge. The other wire of the pair has its starboard end brought up on the inner side of the starboard barge, and its port end over the outside of the port barge. The pairs of wires thus lying on the decks of the barges can then be clamped together when required, and each pair of wires then forms a sort of figure 8 round the two barges with the wreck resting in the bight formed by the cross.

The lifting barges require to have good clear deck spaces and the deck edges should be well stiffened and fitted with chafing plates. At least two powerful winches should be provided, one at each end, and the barges should be fitted with large buoyancy tanks which can be quickly flooded, or pumped out as desired. When all the wires are rove, and the barges are in place, and about 2 hours before the time of low water, the barges are flooded and by means of tackles led to the winches, all the wires are hauled as taut as possible. As near low water as possible the wires are finally tightened up, and then the two wires of each pair are securely clamped together. It is most desirable that all the pairs of wires shall be clamped at practically the same time, and on this account a large number of men are required. A chalk mark placed across each pair of wires serves as a handy indication if there is any slipping in the clamps when the strain comes on. After all clamping is complete the barges are pumped out. If any pair of wires appears to have an undue proportion of the strain, the clamps should be eased slightly to allow the wires to render a little.

As the tide rises, and providing, of course, that the capacity of the barges is sufficient, the vessel will be lifted. If the wreck is in deep water, she can then be towed into a position on a shelving beach where she can be grounded at high water. By repeating the operation the vessel can be eventually placed in a position sufficiently high, so that at low water she will be practically high and dry, and the damage may be repaired and the ship floated in the ordinary manner.

When lifting, in view of the arrangement of the wires, the barges take up a considerable list towards the wreck and are also brought against it with a considerable force—suitable fenders should therefore be provided and the reserve buoyancy of the barges should be sufficient to ensure that the inner deck edge does not become immersed. The illustration on page 532 shows the barges when lifting one of the Zeebrugge block-ships, and indicates the extent of the list and also shows the method of clamping the two wires of each pair.

In the foregoing it has been assumed that the wreck is on an even keel, or practically so, but in some cases it is necessary to first bring the vessel to the upright position. This can usually be done by rigging sheer legs on her upper side, and righting her by means of wires and tackles led to suitable winches, either ashore or mounted on anchored salvage craft, &c. Much can be done to assist the righting operation by the judicious use of water ballast in the vessel, if suitable compartments are watertight or can be readily made so.

NOTES.

The Rating of Machinery.

At a recent meeting of the Liverpool Engineering Society, Mr. E. W. Pierce read a useful paper on the "Rating of Machinery." Mr. Pierce's main point appeared to be that the Poor Rate Exemption Act, 1840, was intended to relieve personal property from liability to be rated, but that its obscure wording led to its effect being imperfectly appreciated, and a practice grew up in many parts of the country of including in the rating of mills, factories and similar premises not only machinery which had been fixed so as to become a part of the premises but also machinery not so fixed which was considered to render the premises suitable for the particular business carried on in them. As time went on this practice became so well established in various parts of the country that judicial notice was taken of it and decisions were given which tended to give it legal recognition. This culminated in the Tyne Boiler Rating Case in 1886 and the case of Kirby *v.* The Hunslet Union in the House of Lords, ten years later. In the latter case Lord Halsbury, in a somewhat petulant judgment, brushed aside counsel's efforts to disturb the existing practice, and stated that the whole question was reduced to a very simple one—"Can you or can you not enhance to any extent the amount of the assessment which you make upon buildings in which there is machinery adapted for the purpose of manufacture, where the manufacture is carried on in them, although the machines do not, as an actual fact, form part of the freehold of the premises?" In view of the long line of previous decisions his lordship was of opinion that this question must be answered in the affirmative. In 1901 the Royal Commission on Local Taxation issued their report recommending that in the estimation of the rateable value of any hereditament occupied for trade, business or manufacturing purposes, there should be excluded from the assessment any increased value arising from machines, tools or appliances which were not fixed or were only so fixed that they could be removed from their place without the removal of any part of the hereditament being necessitated, but that the value of any machinery, machine or plant used in or on the hereditament for producing or transmitting first motive power or for heating or lighting the hereditament should be included. This was given effect to as regards Scotland by the Lands Valuation (Scotland) Amendment Act, 1902, and somewhat similar provisions are in operation in Ireland; but although 17 bills have been introduced into Parliament by private members since 1890 to put matters right as regards England, and nine of them have passed the second reading, the defects of our Parliamentary system and the Government's repeated failure to give the necessary facilities have prevented any of them from becoming law. Such opposition as there was usually came from those interested in agriculture, on the ground that any relief from taxation granted to users of machinery would tend to increase the burden on the rest of the community. It remains to be seen how the Rating of Machinery Bill which has been introduced into the present Parliament will fare. It has been set down for a second reading on May 11. Mr. Pierce agrees with the Federation of British Industries that the present English practice constitutes a heavy burden upon industry and involves a great injustice to owners of machinery.

Structural Engineering.

The distinction between civil and military engineering has frequently been pointed out, and no one with any pretensions to a knowledge of the engineering profession has any excuse for failure to realise that the Institution of Civil Engineers represents civil as distinct from military engineering, and is not in any way exclusively concerned with dock and harbour construction and similar work of the class which is usually referred to as civil. The Institution of Civil Engineers, which was founded in 1818, is the great parent institution which represents every type of non-military engineering activity. Its roll of members and its proceedings carry clear evidence of the wide scope of its interests. Since its founding other great, but specialised, institutions have grown up, making no attempt to compete with the catholicity of the parent body, but concerning themselves with some one branch of work. The chief of these are the Institutions of Mechanical Engineers, Naval Architects and Electrical Engineers. These each deal with one of the important branches into which the whole field covered by the Institution of Civil Engineers may be divided. A branch of work already dealt with by the Institution of Civil Engineers, but which so far has not been taken up by any specialised Institution of the standing of the Institution of the Mechanical and Electrical Engineers, or the Institution of Naval Architects is that of structural engineering, but the newly-formed Institution of Structural Engineers evidently hopes to occupy this position. This body, in its original form of the Concrete Institute, dates from 1908, but it can hardly yet claim to standing and prestige which will put it on a level with the other leading specialised institutions. Its particular line of work, however, lies in an important field which is possibly large enough to carry an institution of its own, and there given wise management and the maintenance of a good standard of membership, there is no reason why the Institution of Structural Engineers should not in due course take its place alongside the other leading specialised bodies. The first presidential address of the new institution, which was delivered by Mr. E. Fiander Etchells in the hall of the Institution of Civil Engineers on the 19th inst., certainly set a good standard. In view of the special nature of the occasion, Mr. Etchells naturally dealt with the formation of the body he represents. His address was a remarkable sketch of the growth of engineering institutions and associations from the earliest times, and showed that even in the dawn of history the builders, surveyors and artificers who were the engineers of those days tended to band together in crafts and associations. Doubtless the bodies of an earlier day had a more political or trades-union aspect than have the professional institutions with which we are familiar, but Mr. Etchells' address none the less established a line of continuity between the new and active body of which he is president and the early guilds of a bygone day.

British Coal Output.—The coal output for the week ended the 14th inst. was 5,776,600 tons; that for the corresponding week of last year was 4,383,800 tons.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 18th inst., at 49, Cromwell-road, South Kensington, Dr. C. Chree, F.R.S., president, in the chair. The following papers were read:—

1. "*An Examination of British Upper Air Data in the Light of the Norwegian Theory of the Structure of the Cyclone*," by Mr. W. H. Dines, F.R.S., and Mr. L. H. G. Dines. A list of dates on which temperature observations were available in England, S.E., was sent to the Meteorological Office, which notified all those on which evidence of the Polar Front might be expected. Graphs of the lapse rate from 0·5 km. to 5 km. were drawn for such dates, but no peculiarities not readily explained by the ordinary casual variation could be found. The lapse rates in general were then examined in connection with the surface pressure, and it is shown that the probability of finding an inversion is almost a linear function of the pressure. The connection between temperature inversions and relative humidity was then examined with reference to 400 kite ascents made at Pyrton Hill, and it was shown that an inversion is nearly always associated with a decrease in the humidity, whereas the Norwegian theory requires an increase. Three special instances were examined in detail. The conclusion reached was that the observational evidence for England fails to support the theory that the superposition of equatorial over polar air is the usual form of the structure of a cyclone.

2. "*On the Mechanism of Cyclones and Anti-Cyclones*," by Mr. T. Kobayasi. This paper offered an explanation of the squall line which is often observed running from near the centre of a cyclone towards the south-west. Mathematical expressions were obtained which represent a cyclone having the following properties: (i) The wind at a fixed level everywhere makes a fixed angle with the isobar and has a fixed fraction of the geostrophic velocity. (ii) In the inner or "principal" part of the cyclone the isobars, except very near the centre, are the contours of a conical pit, and the air is therefore ascending. (iii) In the outer portion of the cyclone there is no vertical velocity. (iv) This distribution is advancing as a whole through air which is calm at a great distance from the centre. The velocity of the centre is less than that of the wind speed in the inner part. The diagrams thus obtained closely resembled the observed features of certain cyclones. It was then shown that as the cyclone advances it draws into its inner region a strip of air lying near the ground in its track, and moves this air up away from the ground. Meanwhile the air outside the two edges of the strip flows round the opposite sides of the cyclone, meeting behind it. Thus if the portions of air outside the two edges of the strip were at different temperatures, as they would often be if the strip lay east and west, then by their contact they would produce the instability, which is characteristic of the squall line.

3. "*Notes on the Fluctuations of Mean Sea-Level in Relation to Change of Atmospheric Pressure*," by Captain E. C. Shankland, R.N.R. The heights to which tides will rise in the principal harbours and estuaries are predetermined by analysis and presented to navigation in the form of tidal predictions. These levels are accompanied by the times of occurrence. Were it not for meteorological interference these predictions could be accepted with a very small margin for actual variation amounting probably to less than 3 in. in level and a proportionate interval of time. The observations of Sir J. Clark Ross, Mr. Daussy and Sir John Lubbock (Senior), with those of more recent dates confirm that the mean sea-level varies inversely with the height of barometer, and a tendency to increase the factor from 13·25 (which may be taken as the specific gravity of mercury as compared with sea water), to a figure approaching 20, are features of the progressive observations when using the mean isobar of the locality as barometric datum. That the exact anticipation is important to harbour administration when the docking and undocking of large deep-draughted vessels is a frequent operation, will be indisputable. From observations extending over a period of autumnal anti-cyclonic weather of considerable geographic extent, results have been obtained by the author which point to the acceptance of a 1/20 factor under these meteorological conditions, the barometric pressure being above normal during the entire series.

PYREX GLASS.—According to a paper by A. E. Marshall, in *Industrial and Engineering Chemistry*, pyrex glass is a borosilicate containing neither heavy metals nor magnesia, lime or zinc oxide. Its expansion coefficient, 0·0000032 per degree Centigrade, is said to be smaller than that of porcelain, viz., 0·0000036, while for ordinary glass the coefficient is 0·0000077 to 0·0000085, and for cast-iron 0·00000102. Pyrex is very little attacked by strong acids, and the attack is soon stopped. The Corning Glass Works, of Corning, New York, now make pyrex sheets of 14 in. by 18 in., retorts of 72 litres (16 gallons) and pots of 9 gallons capacity; a denitrating tower has been made of tubes 6 in. diameter, 8 ft. high. The glass is said to be not liable to break if properly handled, as transparent wares generally are, and this transparency offers another great advantage over stoneware, a strong competitor of glass in chemical works, because cleanliness is easily checked. Insulator bells of pyrex are recommended as superior to porcelain, for one reason because the porcelain gets 3·6 times hotter in the sunshine than pyrex, and further also because any punctures are more uniform in the amorphous glass than in the crystalline porcelain. In fixing the parts of these insulators together use is made of lead strips; the great difference in the expansion coefficients of pyrex and lead is not commented upon by Marshall.

STATIC INDENTATION TESTS.*

By R. G. C. BATSON, Member.

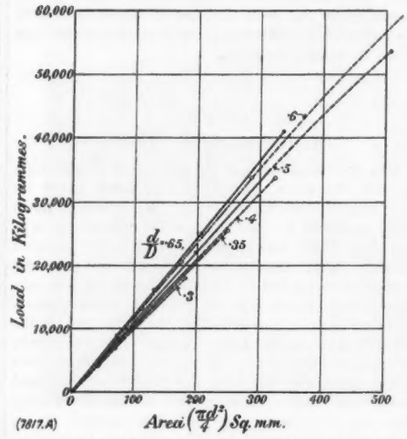
THE paper contains the results of various investigations which have been carried out for, and reported to, the Hardness Tests Research Committee of the Institution of Mechanical Engineers during the years 1919–22, with a view to elucidating various points in connection with the application of the indentation test as a measure of the hardness of materials. The points considered are as follows: (1) Investigation of law of comparison for ball indentation tests. (2) A comparison of the ball and cone methods of test. (3) The determination of the relative hardness of very hard steels by means of ball hardness tests, in which the permanent deformation of the ball is taken as a measure of the hardness of the material producing it.

(1) *Investigation of the Law of Comparison for Ball Indentation Tests.*—In the ordinary practice of determining the hardness of materials by the ball indentation test, it commonly happens that the piece of material available for the test is so small that the standard load of 3,000 kg. cannot be applied. It is, therefore, of considerable importance to know the precise law of comparison which must be followed in these tests in order that the hardness number arrived at may be independent of the dimensions of the ball used.

Such a law of comparison may be derived from the results of Meyer's investigations published in 1908, in which it was revealed that so long as the angle of the impression remained constant, the value of the total load, divided by the projected area of the indentation was also

Fig. 1. INVESTIGATION OF THE LAW OF COMPARISON FOR BALL INDENTATION TESTS.

Curves showing Relation between Pressure and Area of Indentation for Values of the Ratio $\frac{d}{D}$.



constant, or in other words, the condition for constant pressure per unit area of indentation was geometrical similarity of the deformation produced.

Then if d = diameter of indentation,
D = diameter of ball,
P = the total load.

then for $\frac{d}{D}$ = const. (that is, geometrical similarity in deformation) $\frac{P}{\frac{\pi d^2}{4}}$, the hardness number, is constant.

It is evident, therefore, that if for any value of $\frac{d}{D}$ the value of P be plotted on a base of area of indentation, the resulting curve is a straight line, and further that if P *s*. D *s* and d *s* refer to the standard 3,000-kg. test, then to obtain the same hardness number with a ball of diameter D, we must choose P, so that:—

$$\frac{P}{d^2} = \frac{Ps}{ds^2}$$

and since

$$\frac{d}{D} = \frac{ds}{Ds}$$

we must have

$$\frac{P}{D^2} = \frac{Ps}{Ds^2}$$

This is, therefore, the law of comparison for use in the cases mentioned above in which specimens of sufficient size for the 3,000-kg. test are not available.

In view of the importance of the relation, it was considered desirable to undertake an investigation on the range of dimensions over which Meyer's law could be relied upon to a fairly high accuracy, since it appeared from his published papers that he had only used balls of less than 10 mm. diameter in his experiments. For this purpose, steel balls were obtained of the following diameters: 50·8 mm., 31·75 mm., 25 mm., 20 mm., 15 mm., 10 mm. and 5 mm., and special holders were made for them.

* Paper read before the Institution of Mechanical Engineers, on Friday, April 20, 1923.

The material used for the tests was a barof mild steel, 3 in. by 2½ in. (deep), and of uniform hardness. This was machined parallel and one side polished. Five series of tests were made, the value of $\frac{P}{D^2}$ being constant for each series. If, therefore, Meyer's law held, $\frac{d}{D}$ should also be constant for each series. The results of the tests are given in Table I.

TABLE I.—(*Bar 3 In. by 2½ In.*).

Diameter of Ball, Mm. = D.	Load, Kgm. = P.	Diameter of Impression, Mm. = *d*.	Area of Impression $\frac{\pi d^2}{4}$.	Ratio $\frac{d}{D}$
5·0	125	1·345	1·42	0·269
10·0	500	2·65	5·52	0·265
15·0	1,125	3·87	11·76	0·258
20·0	2,000	5·22	21·40	0·261
25·0	3,125	6·46	32·78	0·258
31·75	5,040	8·13	51·91	0·256
50·8	12,900	13·28	138·4	0·261
5·0	250	1·73	2·36	0·346
10·0	1,000	3·525	9·76	0·352
15·0	2,250	5·275	21·85	0·352
20·0	4,000	7·03	38·82	0·351
25·0	6,250	8·77	60·41	0·351
30·75	10,080	11·15	97·6	0·351
50·8	25,800	*17·94	252·8	0·353
5·0	500	2·34	4·30	0·467
10·0	2,000	4·73	17·57	0·473
15·0	4,500	7·17	40·38	0·478
20·0	8,000	9·605	72·45	0·480
25·0	12,500	12·04	113·8	0·482
31·75	20,160	15·33	184·6	0·482
50·8	51,600	*24·82	483·8	0·489
5·0	750	2·825	6·26	0·565
10·0	3,000	5·74	25·88	0·574
15·0	6,750	8·605	58·15	0·574
20·0	12,000	11·50	103·9	0·575
25·0	18,750	14·41	163·1	0·576
31·75	30,240	*18·32	263·6	0·577
50·8	77,420	*30·40	725·8	0·598
5·0	1,000	3·225	8·16	0·645
10·0	4,000	6·48	32·98	0·648
15·0	8,000	9·825	75·81	0·655
20·0	16,000	12·975	132·2	0·649
25·0	25,000	16·33	209·4	0·653
31·75	40,320	*20·54	331·4	0·645
50·8	103,200	—	—	—

* Probably affected by the width of test bar.

TABLE II.—(*Bar 5 In. by 5 In.*).

Diameter of Ball = D.	Load, Kgm. = P.	Diameter of Impression, Mm. = *d*.	Area of Impression, $\frac{\pi d^2}{4}$.	Ratio $\frac{d}{D}$.
10·00	3,000	5·07	20·2	0·507
20·00	12,000	10·12	81·0	0·506
25·00	18,750	12·63	125·0	0·505
31·75	30,240	16·03	202·0	0·505
50·80	77,420	25·56	513·0	0·503

According to a ruling given by H. Moore, the diameter of the test-pieces should be at least 4·5 times the diameter of the impression. According to this rule, the maximum diameter of indentation, with a bar 3 in. wide, should be 17 mm. It will be noted that a few of the impressions (see Table I) are greater in diameter than 17 mm., and these should be ignored in a consideration of the results. they are, however, given in the table for reference. By plotting the curves correlating load and area of indentation for each of the balls used, it was possible to scale off from these curves the value of the load corresponding to any given value of $\frac{d}{D}$. These values have been plotted in Fig. 1, on a base of area of indentation, in the manner suggested by Dr. T. E. Stanton* during the discussion on a previous paper on "Hardness Tests." From this figure and the results in Table I, it will be noted that there is a slight deviation from strict conformity with Meyer's law with the larger sizes of ball, but that the agreement is very good with balls up to 25 mm. and $\frac{d}{D}$ up to 0·65.

A few impressions were made on a larger bar (5 in. by 5 in.) at a part of the bar where the hardness was found to be sufficiently uniform. The results are given in Table II. It will be noted that with this bar the deviation from Meyer's law though small is in the opposite direction from that noted on the first bar. It would appear, therefore, that the cause of the appreciable deviation in the first series of tests with the 50·8 mm. diameter ball is due to the fact that the proximity of the sides of the bar to the indentation affected the results. The general conclusions are that the law of comparison is sufficiently reliable for use in accurate testing practice. It will be noted that, in the above investigation, the projected area of the impression $\left(\frac{\pi d^2}{4}\right.$ where d = the diameter of the impression) has been used throughout in accordance with the method adopted by Meyer. As only geometrically similar impressions are considered, the same conclusion is obtained if the spherical area of the impression, as applied by Brinell, is used. Thus, in order to apply the law of comparison to the Brinell hardness test, so as to

* Proc. I.Mech.E., 1918, page 565.

obtain the same Brinell hardness numbers with balls of different size, it is only necessary to employ loads proportional to the square of the ball diameter. The standard conditions of the Brinell hardness test are obtained with a 10-mm. diameter ball and a load of 3,000 kg. for hard materials, and 500 kg. for soft materials, the hardness number being calculated from the formula :

$$H = \frac{W}{A}.$$

where H = Brinell hardness number.
W = Load in kilogrammes.
A = Spherical area of the impression in square millimetres calculated from the mean diameter of the impression after test.

Corresponding loads and ball diameters for other sizes of ball are given in Table III.

(2) *A Comparison of the Ball and Cone Methods of Indentation Test.*—Ludwik* appears to have been the first to propose substituting a cone of 90 deg. apex angle for the ball in the measurement of indentation hardness. In a description of his "Cone Pressure Test" apparatus, he says : "It is the outcome of efforts to simplify the Brinell test, with the further object of making the hardness number independent of the load and of the dimensions

TABLE III.

Standard Load 3,000 Kg.		Standard Load 500 Kg.	
Diameter of Ball.	Load in Kilos.	Diameter of Ball.	Load in Kilos.
mm.		mm.	
1	30	1	5
2	120	2	20
5	750	5	125
10	3,000	10	500
15	6,750	15	1,125
20	12,000	20	2,000

of the impression. The cause of this dependence we conclude directly from Kick's law of proportional resistances is merely the geometrical dissimilarity of the impressions produced. Hardness numbers always independent of the load can only be realised if the impressions remain geometrically similar for all loads. That will be so when the ball is replaced by a cone."

Ludwik measured the depth of the indentation from the original surface of the material, but he adds a note to the effect that "when the hardness is derived from the diameter of the impression the resulting hardness numbers must likewise be independent of the load." R. P. Devries† in 1911, as a result of some experimental work with both the ball and cone methods of test came to the conclusion that "the cone and sphere tests give results that are quite concordant throughout. For these two tests a strict comparison can be made, for the results are expressed in the same units." Dr. Unwin‡ says "the Ludwik test seems so rational that the reason why it has not got into wider use is surprising. Probably it is because the point of the cone does not stand the pressure put upon it. It is, therefore, useful to point out that a moderately truncated cone would have nearly the same advantage as a complete one." Some results obtained by the author§ showed that manganese steel behaved differently under the cone test from what it did under the ball test, and, therefore, that Devries' conclusion did not hold for this material.

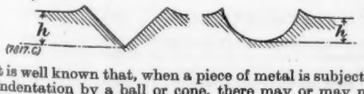
The cone pressure test is largely used on the Continent, and in order to obtain further information relative to the values obtained by this method, when compared with the standard ball method, a series of tests has been carried out on four materials to compare the hardness numbers obtained by using a 10-mm. diameter ball and a 90 deg. cone, when these numbers are in each case calculated from, (1) the diameter of the impressions as obtained by a measuring microscope after the test, and (2) the depth of the impressions when the pressure has been removed, measured from the original surface of the materials.

The materials used were : (*a*) Annealed tool steel ; (*b*) mild steel ; (*c*) 1½-in. diameter brass rod ; (*d*) manganese steel, water quenched from 950 deg. C.

Fig. 2.

(7817.B)

Fig. 3.



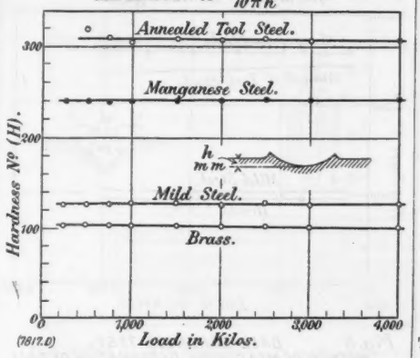
(7817.C)

It is well known that, when a piece of metal is subjected to indentation by a ball or cone, there may or may not be a raised ridge round the impression, as shown in Figs. 2 and 3. Most materials give a ridge, but there are some (*e.g.*, manganese steel) in which there is sometimes a drawing down of the material. It is obvious, therefore, that hardness numbers obtained from the spherical or curved area of the impression are not the same when calculated, (1) from the diameter ; (2) from the depth below the original surface ; also that the results obtained are not directly comparable, the values in one case depending on the amount of "ridge" produced.

There is also another factor affecting the results. The indentation produced by a ball has a larger radius of curvature than the ball used, and the indentation made by a cone has also a larger angle than the angle at the apex of the cone. Thus the curved area calculated from the diameter of the indentation will always be larger than the actual curved area, and the curved area obtained from the depth of the impression will always be less than the actual curved area. This is independent of any effect on the results due to the ridging of the material.

Fig.4. TESTS USING 10 m/m. BALL AND MEASURING THE DEPTH OF IMPRESSION.

$$\text{Hardness No } H = \frac{\text{Load}}{10\pi h}.$$



(7817.D)

With the tests described in this paper the diameters after test were measured by means of a measuring microscope supplied by the Cambridge and Paul Instrument Company, Limited, and reading to 0·01 mm. The impressions were measured in two directions at right angles, and the mean taken for purposes of calculation.

If $\bar{d}$ = the mean diameter of the impression in millimetres obtained after the test by a microscope, Fig. 2.
D = diameter of ball used.
L = load in kilogrammes.

For a ball impression :—

$$\text{Hardness Number (Brinell Method)} = \frac{L}{\text{Spherical Area of Impression in sq. mm.}}$$

$$= \frac{L}{\frac{\pi D}{2}(D - \sqrt{D^2 - \bar{d}^2})}$$

$$= \frac{L}{15{\cdot}71\,(10 - \sqrt{100 - \bar{d}^2})} \text{ for 10 mm. diameter ball.}$$

For 90 deg. cone :—

$$\text{Hardness Number} = \frac{L}{\text{Area of Sides of Conical Impression in sq. mm.}}$$

$$= \frac{L}{\frac{\pi d}{2} \times \frac{d}{\sqrt{2}}}$$

$$= \frac{2\sqrt{2}}{\pi} \times \frac{L}{d^2} = 0{\cdot}90\,\frac{L}{d^2}.$$

For the measurement of depth the Amsler depth indicator was employed. This has been fully described in a paper published in the Proceedings* and reads to 0·01 mm. With this instrument extreme care was necessary in adjusting the zero when using low loads. The instrument was specially mounted in axial loading shackles, so that there was no tilt of the instrument relative to the test specimen during test.

If h = the depth of the indentation below the original surface of the specimen in millimetres, Fig. 3.

For an impressionn with a ball of diameter D :—

$$\text{Hardness Number} = \frac{\text{Load in kilogrammes.}}{\text{Spherical Area of Indentation in sq. mm. calculated from depth below original surface.}}$$

$$= \frac{L}{\pi D h}$$

$$= \frac{L}{31{\cdot}416\,h} \text{ for ball of 10 mm. diameter.}$$

For 90 deg. cone :—

$$\text{Hardness Number (Ludwik Method)} = \frac{\text{Load in kilogrammes.}}{\text{Area of sides of cone in sq. mm. calculated from depth from original surface.}}$$

$$= \frac{L}{\sqrt{2} \cdot \pi h^2} = 0{\cdot}225\,\frac{L}{h^2}.$$

The results obtained by using a 10-mm. ball are given in Table IV, and plotted in Figs. 4 and 5. The results, using a 90 deg. cone, are given in Table V and plotted on Figs. 6 and 7.

The following conclusions are derived from the results of the tests :—

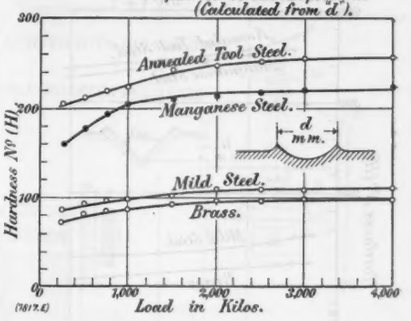
(1) The hardness numbers obtained with a 10-mm. ball and calculated from the diameters of the impressions are not independent of the load. This fact is well known and has been pointed out by many experimenters.

(2) When the depth of the ball indentation (from the original surface) is used for calculating the hardness numbers, the numbers obtained are independent of the load within the range of these experiments. This fact was pointed out by R. P. Devries in 1911 (United States Bureau of Standards Technologic Paper No. 11).

(3) With the cone test the experiments made for the purpose of the present paper appear to show an effect of the opposite kind from that described under

Fig.5. TESTS USING 10 m/m. BALL AND MEASURING THE DIAMETER OF IMPRESSION.

$$\text{Hardness No } H = \frac{\text{Load}}{\text{Spherical Area of Impression (Calculated from } \bar{d}\text{).}}$$



(7817.E)

TABLE IV.—(A) *Tests with 10-mm. Ball Measuring the Depth of the Impression.*

Load in Kg.	500	750	1,000	1,500	2,000	2,500	3,000	4,000
	Annealed Tool Steel.							
Depth of impression in $\frac{1}{100}$ mm.	5·0	7·7	10·5	15·5	20·7	25·8	31·2	41·5
Hardness No.	318	310	304	308	308	309	306	307
	Mild Steel.							
Depth of impression in $\frac{1}{100}$ mm.	12·7	19·0	25·3	37·3	50·0	62·0	75·5	100·0
Hardness No.	125	126	126	128	127	128	126	127
	Brass Rod.							
Depth of impression in $\frac{1}{100}$ mm.	15·8	23·4	30·9	46·7	62·1	77·9	93·4	126·0
Hardness No.	101	102	103	102	102	102	102	101
	Water-Quenched Manganese Steel.							
Depth of impression in $\frac{1}{100}$ mm.	6·6	10·0	13·3	20·0	26·5	33·0	39·5	53·0
Hardness No.	241	239	240	239	240	241	242	240

(B) *Tests with 10-mm. Ball Measuring the Diameters of the Impression.*

Load in Kg.	250	500	750	1,000	1,500	2,000	2,500	3,000	4,000
		Annealed Tool Steel.							
Diam. of impression in mm.	1·25	1·735	2·075	2·37	2·78	3·185	3·505	3·795	4·34
Hardness No. (Brinell)	204	211	219	224	242	247	251	256	257
		Mild Steel.							
Diam. of impression in mm.	1·97	2·60	3·10	3·54	4·25	4·66	5·15	5·66	6·37
Hardness No. (Brinell)	87	93	97	98	101	110	111	109	111
		Brass Rod.							
Diam. of impression in mm.	2·10	2·76	3·26	3·72	4·42	4·96	5·53	5·91	6·72
Hardness No. (Brinell)	72	82	87	88	92	97	96	99	97
		Water-Quenched Manganese Steel.							
Diam. of impression in mm.	1·40	1·88	2·21	2·47	2·99	3·41	3·76	4·07	4·62
Hardness No. (Brinell)	159	176	194	205	210	212	217	221	224

* "Hardness Tests," by P. Ludwik. Proc. International Association for Testing Metals, Fifth Congress. Copenhagen, 1909.

† "Methods of Hardness Measurement," by R. P. Devries. Proc. Amer. Soc. of Testing Materials. Vol. xi, page 717.

‡ Ludwik Hardness Test, by W. C. Unwin. Proc. I.Mech.E., 1918, page 485.

§ Proc. I.Mech.E., 1918, page 592.

* Proc. I.Mech.E., 1920, page 941.

conclusions (1) and (2) for the ball test. The hardness numbers calculated from the diameters of the impression (using the conical area of the impression as recommended by Ludwik) are approximately constant and those obtained from the depth of the indentation vary with the load.

(4) It follows from conclusions (1), (2) and (3), that

Fig. 6. TESTS USING 90° CONE AND MEASURING DEPTH OF IMPRESSION.

Hardness No. $H = \frac{Load}{\pi h^2 \sqrt{2}}$.

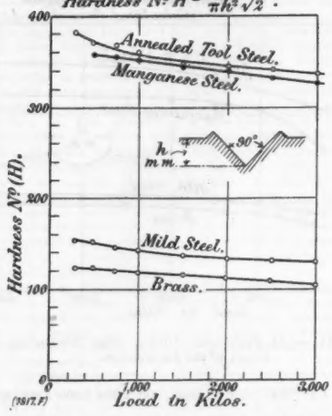


TABLE V.—(A) *Tests with 90 Deg. Cone Measuring the Depth of the Impression.*

Load in Kg.	300	500	750	1,000	1,500	2,000	2,500	3,000
	Annealed Tool Steel.							
Depth of indentation in $\frac{1}{100}$ mm.	42·0	55·0	67·6	79·0	98·5	114·0	128·0	142·0
Hardness No. (Ludwik)	383	371	369	361	348	346	343	335
	Mild Steel.							
Depth of indentation in $\frac{1}{100}$ mm.	66·5	86·0	107·5	126·0	156·6	183·0	205·5	227·0
Hardness No. (Ludwik)	153	152	146	142	138	135	133	131
	Brass Rod.							
Depth of indentation in $\frac{1}{100}$ mm.	74·0	95·7	118·6	138·0	170·0	199·5	227·5	253·0
Hardness No. (Ludwik)	123	123	120	118	117	113	109	105
	Water-Quenched Manganese Steel.							
Depth of indentation in $\frac{1}{100}$ mm.	—	56·0	69·0	80·0	99·0	115·0	130·0	144·0
Hardness No. (Ludwik)	—	359	355	352	345	341	333	326

(B) *Tests with 90-Deg. Cone Measuring the Diameter of the Impression.*

Load in Kg.	250	500	750	1,000	1,500	2,000	2,500	3,000
	Annealed Tool Steel.							
Diameter of impression in mm.	0·97	1·365	1·685	1·94	2·39	2·775	3·105	3·45
Hardness No.	239	241	238	239	236	234	233	227
	Mild Steel.							
Diameter of impression in mm.	1·49	2·10	2·58	3·00	3·65	4·23	4·63	5·17
Hardness No.	101	102	101	100	101	101	105	101
	Brass.							
Diameter of impression in mm.	1·54	2·20	2·68	3·09	3·82	4·40	4·95	5·45
Hardness No.	95	93	94	94	93	93	92	91
	Water-Quenched Manganese Steel.							
Diameter of impression in mm.	0·94	1·33	1·61	1·88	2·30	2·67	2·98	3·23
Hardness No.	255	254	260	255	256	253	254	258

with varying loads the complete impressions with the ball test are dissimilar, and with the cone test are similar. It also follows that, when the part of the impression caused by the "ridge" is neglected, the impression under varying loads given by the ball test, are similar and by the cone test are dissimilar.

(5) The hardness numbers with a load of 3,000 kg., calculated as previously described, are summarised in Table VI, and the ratios between the ball and cone test results are also given. These show that, whereas for three of the materials the ratio is approximately the same, for manganese steel the cone test gives a much higher relative result than the ball test. For this reason it is not possible to give a definite ratio under these conditions between ball test results and cone test results for all materials.

It will be noticed that for the three materials and with the methods of calculation adopted, the ball test gives numbers which are from 8 per cent. to 13 per cent. higher

Fig. 7. TESTS USING 90° CONE AND MEASURING DIAMETER OF IMPRESSION.

Hardness No. $H = 0{\cdot}90 \frac{Load}{d^2}$.

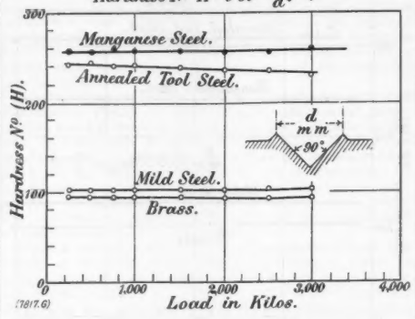


Fig. 8. BALL HARDNESS TEST. METHOD OF MEASURING DEFORMATION OF BALL.

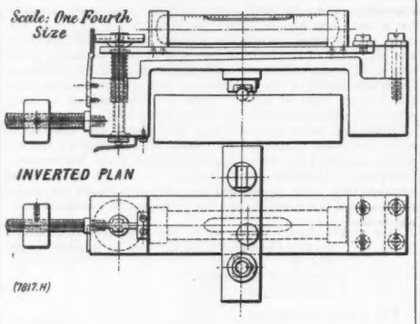


Fig. 9. BALL HARDNESS TEST. METHOD OF MEASURING DEFORMATION OF BALL.

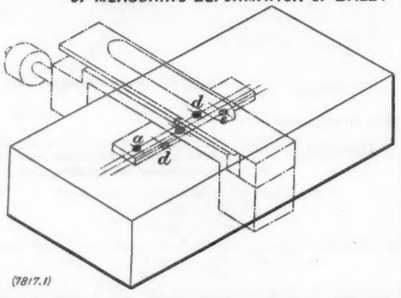


TABLE VI.—*Hardness Nos. with a Load of 3,000 Kg.*

Material.	Hardness No. from Diameter. Ball.	Cone.	Ratio Ball / Cone.	Hardness No. from Depth. Ball.	Cone.	Ratio Ball / Cone.
Annealed tool steel	256	227	1·13	306	335	0·91
Mild steel ..	109	101	1·08	126	131	0·96
Brass rod ..	99	91	1·09	102	105	0·97
Manganese steel	221	258	0·86	242	326	0·74

than the cone test numbers when using the diameter of the indentation, and 3 per cent. to 9 per cent. lower when using the depth of indentation from the original surface of the test-piece. It was suggested that in order to obtain the same hardness number for both ball and cone tests, the hardness number should be taken as equal to :—

$$\frac{\text{Load}}{\text{projected area of indentation}} = \frac{L}{\pi d^2},$$

where L = load and d = diameter of the indentation. By adopting this method of calculation, the cone hardness numbers would be 41·4 per cent. higher and the ball hardness numbers less than 12 per cent. higher (this depending on the diameter of the indentation) than those obtained by the method previously described. There would thus be a still greater difference between the cone and ball hardness test numbers if this method of calculation was used.

(3) *The Determination of the Relative Hardness of Very Hard Steels by means of Ball Hardness Tests in which the Permanent Deformation o the Ball is taken as a Measure of the Hardness of the Material producing it.*—It is well known that for steels whose hardness number on the Brinell scale exceeds 600 the Brinell method is unsatisfactory, on account of the permanent deformation produced on the ball. If, therefore, a sufficiently sensitive and accurate method of measuring the amounts of permanent deformation produced in balls of the same hardness by specimens of varying hardness could be devised, such deformations might be correlated to the hardness of the specimens. Further, if by this means a more open scale could be obtained for the harder material than is possible with existing methods, such a comparison might be of considerable value as a practical test of the relative hardness. An attempt has been made to devise an instrument on these lines. Previous experience has shown that, for the measurement of very minute differences in the linear dimensions of two bodies of approximately the same size, a very sensitive spirit level is particularly desirable. A level of 126 ft. radius was procured from the Metrology Department, N.P.L., and mounted in a steel sleeve provided with a hardened steel base plate. This base plate was arranged to rest on three steel balls embedded in a block of mild steel, the balls forming a triangle of which the base subtended an angle of about 170 deg., and the ball forming the apex of the triangle was the test ball. Any permanent flattening of the test ball would tilt the base plate and the movement of the bubble of the spirit level, whose axis was at right angles to the base of the triangle, would be a measure of the flattening. Some preliminary experiments having indicated that the method was a promising one, the instrument illustrated in Figs. 8 and 9 was constructed. Fig. 9 is a diagrammatic view of the test block which holds the test and reference balls *a, b, c, d, e*. These five impressions are carefully made by forcing 10-mm. balls into the block up to a pressure of 5,000 kg. *c*, which forms the common apex of the two triangles *c a b*, *c d e*, is the impression into which the test ball is fitted, four other balls of the same diameter and hardness being placed on *a, b, d* and *e*. The test block is then placed on the platen of the testing machine and the levels of the test ball relative (1) to *a* and *b*; and (2) to *d* and *e*, are carefully taken. The object of the double triangle is to eliminate any disturbance in the level of the test block between the readings before and after the test. A load of 3,000 kg. is then applied to the test ball through the sample of steel of which the hardness is required. On removing the load the levels are taken as before, and the amount of deformation of the test ball is noted. It will be realised that for the refined measurements required, it is necessary that the contact points of the table, and the reference balls should be identical in each experiment. The manner in which this is ensured will be clear from the inverted plan of the base plate shown in Fig. 8. One of the reference balls fits into a recess in which three small steel balls are symmetrically disposed and the other reference ball rests on the sides of a V-shaped groove cut in the base plate.

The method of using the level is illustrated in the side view of Fig. 8, from which it will be seen that the differences in level are measured by a micrometer attachment by means of which the bubble is brought to the middle of its run at each observation, and the deflection read off on the graduated head.

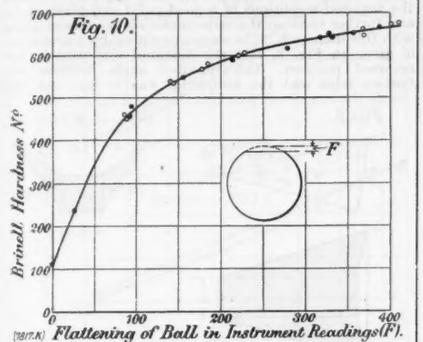
Tests have been carried out on, (1) six steel specimens

TABLE VII.

No. Particulars of Sample.	Brinell Hardness No.	Flattening of Ball in Instrument Readings.
Brass rod	113, 113, 114 → 113	0·5, 0·0, 0·0 → 0
Annealed tool steel	239, 240, 239, 238 → 239	27, 27, 29, 22 → 26
3137. D. 1 nickel-chromium steel ..	455, 463	87, 84
Tool steel hardened and tempered..	460, 483	90, 93
3137. D. 5 nickel-chromium steel ..	537, 540	142, 139
Tool steel hardened and tempered..	549	153
3137. D. 4 nickel-chromium steel ..	570, 581	176, 183
Tool steel hardened and tempered..	591	212
3137. D. 12 nickel-chromium steel..	600, 606	219, 226
Tool steel hardened and tempered..	616	277
Tool steel hardened and tempered..	642, 642, 652	316, 330, 327
Tool steel hardened and tempered..	652	356
1935. 1 high-carbon steel (1 per cent. carbon)	646, 660	369, 367
Tool steel hardened and tempered..	664	387
2017. A chromium steel	671, 677	401, 410

of varying hardness, kindly supplied by Sir Robert Hadfield; (2) pieces cut from a bar of tool steel, and (*a*) annealed, (*b*) hardened and tempered at seven different temperatures; (3) brass rod.

The result of the tests are given in Table VII, and plotted against the corresponding Brinell hardness numbers in Fig. 10. It will be seen that the deformation scale is a very open one for the harder materials, and in



(7817.K) *Flattening of Ball in Instrument Readings (F).*

the hands of a careful observer a satisfactory uniformity in tests can be obtained. In an examination of the curve in Fig. 10, it should be borne in mind that, even with very careful polishing of the test pieces, the measurements of the diameters of the impressions on very hard materials cannot be obtained with very great accuracy. The Brinell hardness numbers are, therefore, not to the same degree of accuracy as the ball-flattening measurements. All the tests were made on balls from one batch supplied by the Hoffman Manufacturing Company, Limited, and are their standard product. One instrument division corresponds to a flattening of the ball of 0·0000032 in., that is, an instrument reading of 410 corresponds to a flattening of

$$410 \times 0{\cdot}0000032 \text{ in.} = 0{\cdot}00131 \text{ in.}$$

The results are accurate to $\pm$ 0·00001 in.

It has been shown* that with Brinell hardness tests on hard materials, the hardness numbers obtained depend upon the material and hardness of the ball used for the test. Values obtained by different observers sometimes differ by 50–100 points on the Brinell hardness scale. The method of test outlined above appears to be a useful one for laboratory purposes in investigating differences in the hardness of materials in the upper ranges, where the ordinary methods are inadequate.

THE RELATION BETWEEN WIDTH OF SCRATCH AND LOAD ON DIAMOND IN THE SCRATCH HARDNESS TEST.†

By G. A. HANKINS, A.R.C.Sc.

THE experiments described in the present paper have been carried out at the National Physical Laboratory for the Hardness Tests Research Committee of the Institution. The work was suggested originally by Dr. Unwin, who considered that the relation between the width of the scratch and the hardness number required further investigation.‡

In the machine designed and constructed for the purpose of this research the first method adopted was one by means of which the depth of a scratch made by a diamond point on an inclined specimen could be measured. The load was applied by a spring, and the inclined plane of the specimen gave uniform increase of the load as the diamond moved over the surface of the material. Preliminary observations with this apparatus appeared to indicate that the depth of the scratch was simply proportional to the load. In view of the unexpected character of these results, it was decided to examine carefully the actual manner in which the material was removed by the action of the diamond point, and for this purpose the apparatus was modified so that scratches under constant load could be made, and then examined under the microscope and their widths determined.

The general arrangement of the instrument as used for this work is shown in Fig. 1. The test-piece was clamped to the block either horizontally or at the angle of the block. The diamond holder was fixed in a rod that was free to move vertically in the bridge of the apparatus, and the orientation of the diamond was also fixed. Weights were placed on the top of the rod to which the diamond was fixed, and the latter was slowly lowered on to the test surface. A scratch was then obtained by turning the leading screw of the block to which the test-plate was clamped. The microscope used for the measurement of the scratches was fitted with oil immersion objective and travelling wires in the eyepiece. The use of the microscope has given direct observation of the scratches and enabled the observer to form definite ideas of the behaviour of the metal under the diamond when a scratch was made. The microscope was calibrated against a diffraction grating having 14,400 lines per inch. The shapes of the available diamonds as shown by a 50 to 1 projector are given in Fig. 2, diamond No. 1, being a pyramid with a large vertical angle and diamond No. 2, similar in shape to a V-thread cutting tool. In diamond No. 1, it was noticed that the edges formed by the junctions of the plane faces were not at right angles (see Fig. 3*e*), and that the point was not good when viewed under the microscope. The bottom edge of diamond No. 2 appeared to be a fairly uniform flat of width 0·004 mm. to 0·005 mm. (see Fig. 3*a*).

Preliminary Tests.—As a preliminary, tests were made to ascertain whether uniform scratches could be obtained on a horizontal test-piece using a total load of 69·1 grammes on the diamonds. The speed of cutting was slow, of the order of 1¼ in. per minute, and this was maintained as uniform as was possible by hand. Several scratches were made with both diamonds under apparently identical conditions, examined under the microscope, and the following general observations were made.

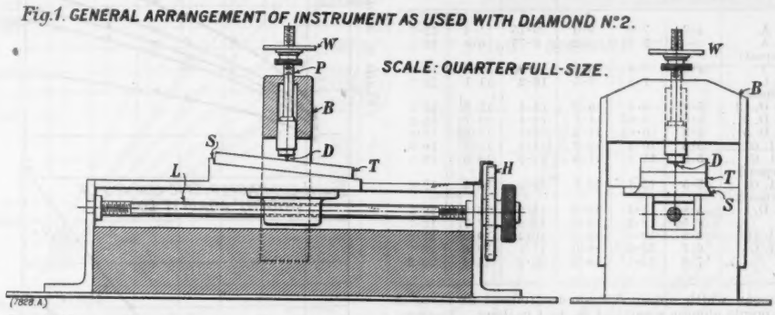
Diamond No. 1.—Individual scratches were not very uniform in width throughout the length of a scratch, the edges were ragged and consequently accurate measurements of widths were not possible. The mean widths of different scratches varied by 20 per cent. of the mean width of the smallest scratch. With the diamond turned through 180 deg., scratches were obtained with similar variations, but the edges were slightly more ragged.

Diamond No. 2.—The diamond was first used with the flat vertical face to the front, and the scratches obtained in this way were sharply defined with good edges, but measurements showed that, at the load and speed stated, the width of a scratch increased continuously from start to finish so that in one case it was nearly doubled in a length of 1 in. The rate of increase of width varied in different scratches, but all showed a marked increase along the scratch. It was also noticed that the use of the diamond in this way produced small shavings of the test material which were thrown out at the side of the scratch. The diamond was then tried in the reversed position, as shown in Fig. 3*c*, but on the horizontal plate as before. The scratches obtained were uniform along the lengths of individual scratches, and the mean widths of different scratches were in agreement with each other. The edges were distinct and hence the widths could be measured more accurately than with diamond No. 1. No shavings of the material were seen, but slight surface distress was noticed on the material near the edges of the scratches.

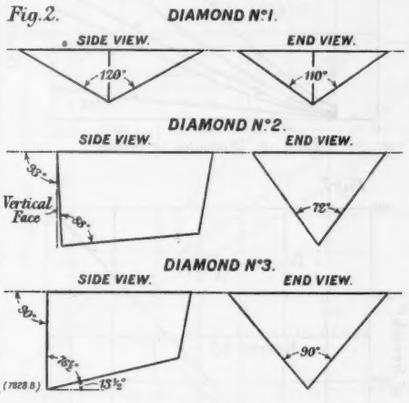
For the above observations it was necessary to level the test-piece by setting up one end, since the movable block of the instrument was inclined at an angle of approximately 6 deg. to the horizontal. For convenience in use it was easier to clamp a parallel test-piece at the angle of the block. Several scratches, using diamond No. 2 in the reverse position, were made on different materials with the test-pieces inclined in this manner. Sharply defined uniform scratches were obtained, repeat tests on the same materials were in agreement, and the widths of the scratches on the different materials were in the reverse order to the Brinell Hardness numbers.

The formation of a scratch by diamond No. 2 in the reversed position appeared to be of the nature of a flow of the material under the leading surfaces of the diamond, and experience with the diamonds led to the conclusion that scratches obtained in this way were desirable if sharply defined edges and uniform results were to be obtained. This is in agreement with the experience obtained at the laboratory in ruling diffraction gratings with a fine diamond point. The speed is higher than that used in the present tests, but experience has shown that the most satisfactory scratches are obtained when the cutting is silent and no particles of the metal are actually removed by the diamond. No detailed observations of the effect of speed were made, but small variations from that given had no appreciable effect on the scratches obtained.

Comparison of Scratches on Different Materials using



B = Bridge. D = Diamond. H = Handwheel for moving block. L = Leading screw. P = Spindle free sliding fit in bridge. S = Sliding block. T = Test-piece. W = Weight.



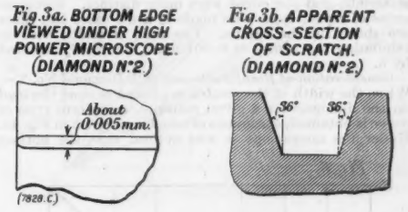


Fig. 3a. BOTTOM EDGE VIEWED UNDER HIGH POWER MICROSCOPE. (DIAMOND N°2.)
About 0·005 mm.
(7829.C.)
Fig. 3b. APPARENT CROSS-SECTION OF SCRATCH. (DIAMOND N°2.)
36°
36°

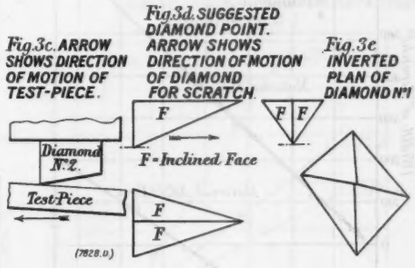


Fig. 3c. ARROW SHOWS DIRECTION OF MOTION OF TEST-PIECE.
Diamond N°2.
Test-Piece
Fig. 3d. SUGGESTED DIAMOND POINT. ARROW SHOWS DIRECTION OF MOTION OF DIAMOND FOR SCRATCH.
F
F-Inclined Face
Fig. 3e. INVERTED PLAN OF DIAMOND N°1
F F
(7828.D.)

TABLE I.—*Materials Used in the Tests.*

Reference Mark of Material.	Material.	Brinell Hardness No.
2017. A. ..	Hardened chromium steel	674
1935. 1 ..	Hardened 1 per cent. carbon steel ..	653
3137. D. 12	Nickel-chromium steel	602
3137. D. 4	Nickel-chromium steel	576
3137. D. 5	Nickel-chromium steel	539
3137. D. 1	Nickel-chromium steel	459
AEN1. G. ..	Tool steel AEN, tempered to 300 deg. C.	528
AEN1. D. ..	Tool steel AEN, tempered to 600 deg. C.	246
AEN1. C. ..	Tool steel AEN, annealed	195
T.S.	Tool steel, annealed	289
M.S. ..	Mild steel	118

The first six of the above specimens were kindly supplied by Sir Robert Hadfield.

Diamond No. 2.—In view of the above preliminary observations it was decided to make detailed measurements of scratches on various materials using diamond No. 2 in the reversed position, with the vertical face to the rear, the test-piece at the angle of the block, and moving the block so that the relative motion of the diamond was down the inclined surface of the test-piece as shown in Fig. 3*c*. Eleven different specimens were used for the tests, and details of these, together with the Brinell hardness numbers, are given in Table I.

The load used in the preliminary tests was arbitrary, but a little experience with different materials showed that less than 20 grammes load gave a very small scratch on a hard material, and that about 190 grammes on a mild steel gave a comparatively large scratch with rough edges. Accordingly, scratches were made on each material at six different loads between those mentioned, as it was considered that this would enable better comparative results to be obtained and that some relation

* *Chem. and Metall. Eng.*, November 8, 1922, page 924.

† Paper read before the Institution of Mechanical Engineers, on Friday, April 20, 1923.

‡ ENGINEERING, November 21, 1919.

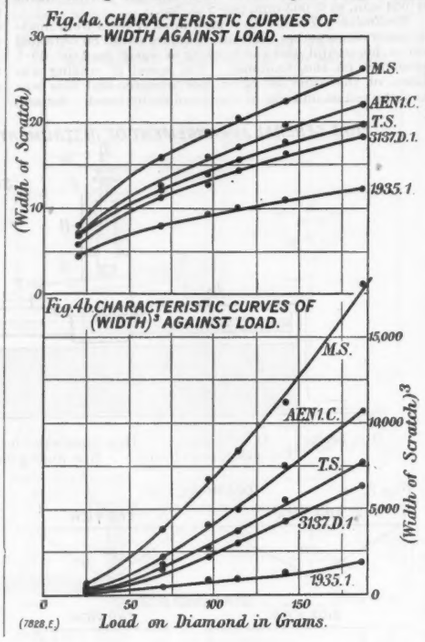
between the width of a scratch and the load might be established. The surfaces of the materials tested were ground, and then polished with fine emery before the scratches were made. No lubricant was used on the surfaces of the materials. The results obtained are given in Table II, below, and each value given represents

TABLE II.—*Diamond No. 2.*

Reference Mark of Material.	Width of Scratch in μ at Load of					
	20·5 Grm.	69·1 Grm.	95·8 Grm.	113·5 Grm.	141·1 Grm.	186·4 Grm.
2017. A. ..	4·7	7·8	9·0	10·15	11·4	12·7
2017. A. .. (Repeat)	—	7·85	9·2	9·75	10·8	12·4
1935. 1 ..	4·6	7·9	9·35	9·95	10·9	12·4
1935. 1 .. (Repeat)	—	7·8	9·5	10·2	11·1	12·1
3137. D. 12	5·0	9·4	10·9	11·4	12·6	14·5
3137. D. 4 ..	5·6	9·65	11·1	12·4	13·7	15·2
3137. D. 5 ..	5·3	10·05	11·3	12·1	13·65	15·9
AEN1. G. ..	5·6	10·3	12·6	13·5	15·1	16·8
AEN1. G. .. (Repeat)	5·3	11·2	11·8	12·9	14·6	16·9
AEN1. G. .. (Repeat)	5·5	11·4	12·1	12·9	14·5	16·8
3137. D. 1 ..	5·85	11·4	13·0	14·5	16·3	18·4
T.S. ..	6·55	12·3	14·0	15·6	17·7	19·7
AEN1. D. ..	6·6	12·4	15·2	16·4	19·3	21·9
AEN1. C. ..	6·7	12·8	16·0	17·1	19·6	22·1
M.S. ..	7·8	15·8	18·9	20·4	22·4	26·2

the mean width obtained by measurement at three or four points along a scratch, $\frac{1}{4}$ in. to 1 in. long. Measurements of widths along a scratch were usually within $\pm$ 0·0003 mm. of the mean width. Generally, the hard materials gave more uniform scratches than the soft materials, and the edges were more distinct. Complete series of repeat tests were made in some cases and these are shown in the results. The unit of width used in tabulating the results is 0·001 mm., commonly denoted by μ.

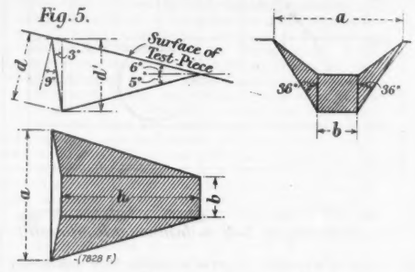
Consideration of Results obtained with Diamond No. 2.—When the width of the scratch is plotted against the load on the diamond for a given material, a uniform type of curve is obtained, specimens of which are shown in Fig. 4*a*. Under the microscope it was noticed that the bottom of a scratch appeared as a parallel band and this band remained a constant width for all scratches. Interpretation of what is seen under the microscope is sometimes difficult, but there seemed good grounds for assuming that the bottoms of all the scratches were approximately flat, and that the cross-section was similar to that shown in Fig. 3*b*. This was further supported by the shape of the diamond point itself, as mentioned previously, and by the scratches obtained with the smallest load on the hard materials. The latter appeared as two dark lines a uniform distance apart corresponding to the width of the flat on the edge of the diamond, and the depths of such scratches seemed very small. All the test scratches appeared to be formed by flow of the material from under the leading faces of the diamond, and no shavings of the test material were observed. Thus, with a diamond point as shown in Fig. 3*d*, it seems probable that a scratch would be formed by flow of the material at the two inclined faces, and that the load on the diamond would be proportional to the area of these faces projected on to the horizontal plane, and, therefore, to the square of the width of the scratch. In the case of the scratches obtained, the apparent flat at the bottom is an added complication. Assuming that the edges of diamond No. 2 are perfect, the leading faces of the diamond in contact with the metal in the formation of a scratch, are of the form shown in Fig. 5. The projected areas of these faces on the horizontal plane is shown to be a straight line function of the square of the width (Fig. 5). Hence, for a given material and using this diamond, the square of the width of a scratch plotted against the load will probably give a straight line not passing through the origin.



The results obtained by plotting the square of the width of a scratch against the load are shown in detail for each material in Figs. 6 to 9. It is seen that approximate straight lines are obtained in all cases. The lines are also shown transferred to the same diagram in Fig. 10. They tend to intersect at the same point, and it seems possible that a measure of the hardness of each material may be obtained from the slope of the corresponding line in this diagram. The type of curve obtained by plotting the cube of the width of the scratch against the load is shown in Fig. 4*b*.

Confirmatory Tests.—The results so far obtained seemed encouraging, and it was decided to obtain another diamond for confirmatory tests. It was thought that a diamond with a perfectly sharp point and plane faces would afford the most instructive results. The diamond merchants consulted expressed the view that the preparation of a perfectly sharp point would be extremely difficult, and no guarantee of the accuracy of the faces to specified angles could be given. A few diamond fragments were, therefore, examined to see if very sharp points arose when accidental cleavage of the diamond occurred. Very good points were found, but it appeared that the areas of the plane face at the points were too small to allow of satisfactory use in the present type of test. At the second attempt a polished diamond (diamond No. 3) was prepared which appeared to meet the required conditions of a good point and plane faces, and further tests on the same materials have been made with this diamond. The shape, as shown by a projector, is given in Fig. 2, and the diamond was used in the reversed position. The specified angle between the bottom edge and the horizontal was 5 deg., but the actual angle was 13½ deg. A few tests were made in an exactly similar manner to those made with diamond No. 2, but the scratches obtained were somewhat ragged and measurement was difficult. Similar results were obtained when the test-piece was horizontal, and in both cases it was thought that the angle of the bottom edge with the horizontal was too great for good scratches to be produced. In view of this the diamond was mounted as shown in Fig. 11, so that this angle was reduced to 3½ deg. The spring holding the diamond was thin and wide and was set in the same vertical position relative to the surface of the material in all the tests. A small load gave a large movement of the spring when the diamond was unsupported, but when the diamond was resting on the horizontal test-piece the spring was in its mean position. Thus, small variations from the mean position, due to surface irregularities and different scratch depths, did not alter appreciably the load on the diamond point, but the spring was sufficiently stiff to retain the diamond at a constant angle to the surface of the test-piece. The load on the point was varied by the direct application of weights immediately over the diamond.

The results obtained with diamond No. 3 in this manner



a = Width of scratch at top. b = Width of scratch at bottom. d = Depth of scratch perpendicular to surface of material.

Leading faces of diamond in contact with material shown shaded.

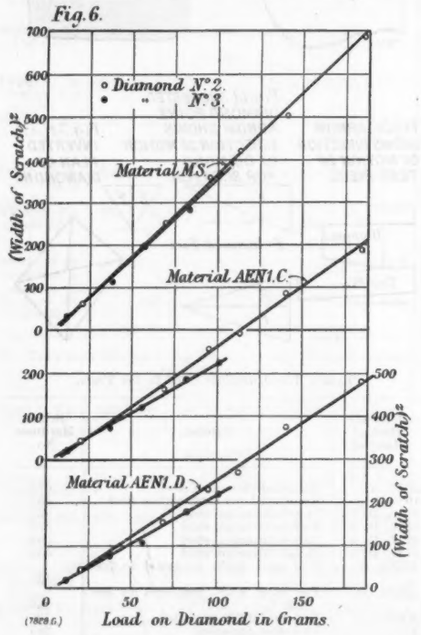
Projected area of these on horizontal plane $= \frac{1}{2}(a + b)\,h$.

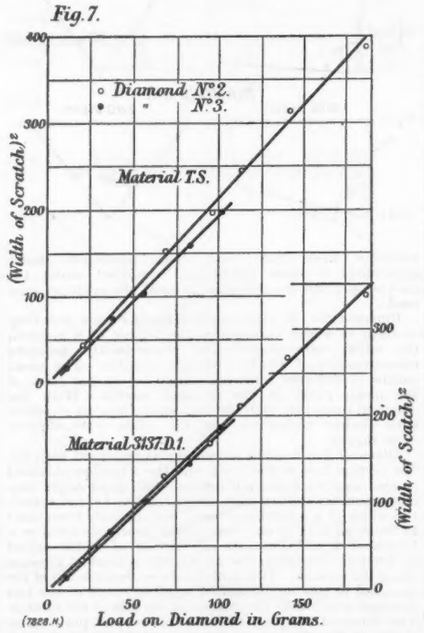
$$d' = d\,\frac{\cos 3^\circ}{\cos 9^\circ} = \frac{a-b}{2}\cot 36^\circ \times \frac{\cos 3^\circ}{\cos 9^\circ}$$

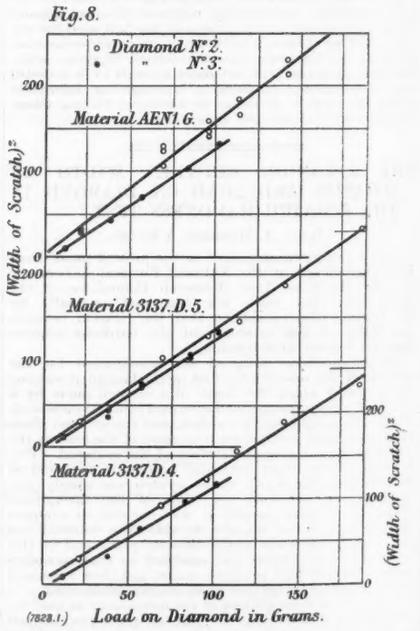
also $d' = h \tan 5^\circ + h \tan 6^\circ$ (nearly),

$\therefore\ h = d' \times (a \text{ constant}) = (a-b) \times (a \text{ constant})$.

$\therefore$ Projected area $= \frac{1}{2}(a + b)\,h = (a^2 - b^2) \times (a \text{ constant})$ approximately.







THE DIAMOND SCRATCH HARDNESS TEST FOR METALS.

Fig. 9.

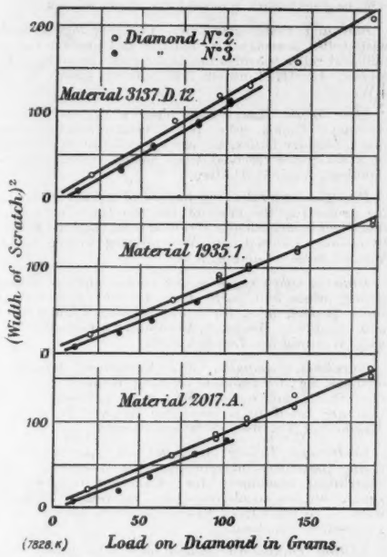


Fig. 10. DIAMOND N°2.

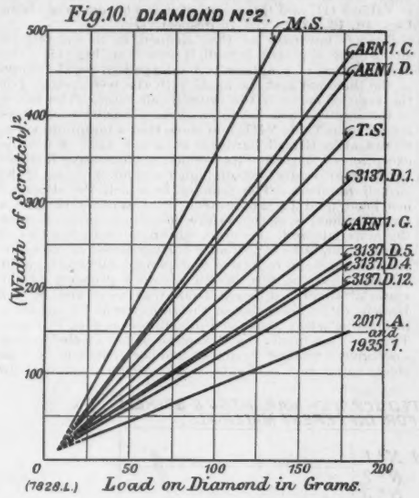


Fig. 11. ARRANGEMENT OF SPRING HOLDER AS USED WITH DIAMOND N° 3.

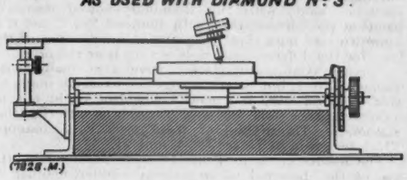


Fig. 12. DIAMOND N° 3.

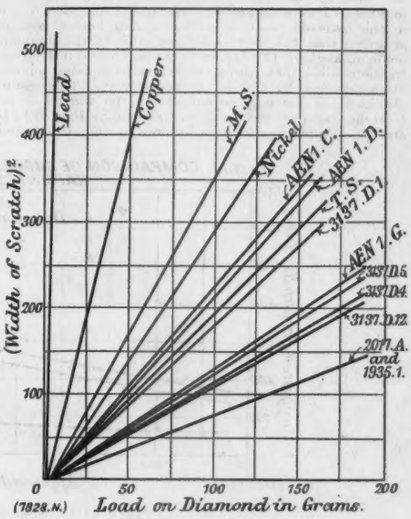


Fig. 13. DIAMOND N°1. DOWN INCLINE OF INSTRUMENT. (CONDITION B.)

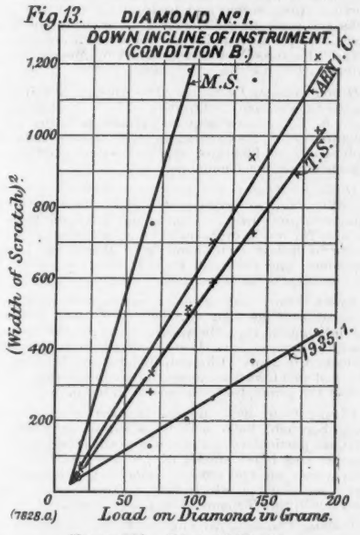


Fig. 14. DIAMOND N°1. ON LEVEL PLATE. (CONDITION C).

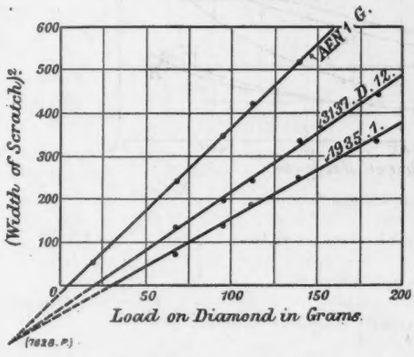


Fig. 15. DIAMOND N°1. SPRING HOLDER, DIAMOND REVERSED. (CONDITION A.)

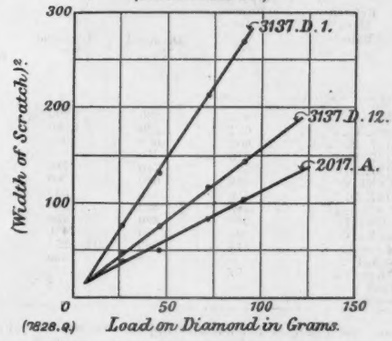
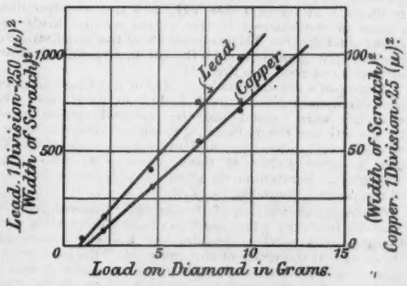


Fig. 16. DIAMOND N°3.



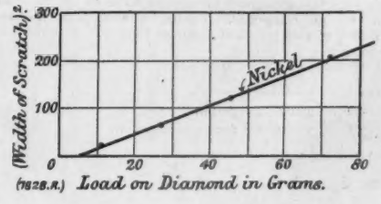


TABLE III.—*Diamond No.* 3.

Reference Mark of Material.	Width of Scratch in μ at Load of				
	11·1 Grm.	37·8 Grm.	56·4 Grm.	83·1 Grm.	101·7 Grm.
2017. A. ..	2·5	4·4	6·0	7·9	8·85
1935. 1 ..	2·3	4·6	6·1	7·7	8·8
3137. D. 12 ..	2·7	5·6	7·6	9·2	10·5
3137. D. 12 .. (Repeat)	2·7	5·9	7·7	9·3	10·6
3137. D. 4 ..	2·9	5·8	8·0	9·85	10·8
3137. D. 5 ..	3·35	6·0	8·5	10·25	11·5
3137. D. 5 .. (Repeat)	3·15	6·5	8·3	10·15	11·6
AEN1. G. ..	3·3	6·6	8·4	10·2	11·5
3137. D. 1 ..	3·9	8·1	10·15	12·2	13·7
T.S.	4·15	8·6	10·2	12·6	14·1
AEN1. D. ..	4·3	8·75	10·3	13·4	14·65
AEN1. C. ..	4·3	8·7	11·2	13·6	15·1
M.S.	5·3	10·7	13·9	16·8	19·1

TABLE IV.—*Diamond No.* 1. *Down Incline.* (*Condition B*)

Reference Mark of Material.	Width of Scratch in μ at Load of					
	18·5 Grm.	67·1 Grm.	93·8 Grm.	111·5 Grm.	139·1 Grm.	184·4 Grm.
1935. 1 ..	6·65	11·3	14·3	16·3	19·2	21·3
T.S. ..	8·8	16·7	22·3	24·3	26·9	32·0
AEN1. C. ..	7·35	18·1	22·8	26·4	30·6	34·9
M.S. ..	11·7	27·3	34·3	37·6	45·7	50·8

TABLE V.—*Diamond No.* 1, *on Horizontal Test-Piece.* (*Condition C.*)

Reference Mark of Material.	Width of Scratch in μ at Load of					
	18·5 Grm.	67·1 Grm.	93·8 Grm.	111·5 Grm.	139·1 Grm.	184·4 Grm.
1935. 1 ..	—	8·6	11·9	13·7	15·7	18·3
3137. D. 12	—	11·6	14·2	15·7	18·3	21·2
AEN1. G. ..	7·5	15·6	18·7	20·4	22·8	26·4

TABLE VI.—*Diamond No.* 1, *Reversed Position on Spring Holder.* (*Condition A.*)

Reference Mark of Material.	Width of Scratch in μ at Load of			
	26·7 Grm.	45·3 Grm.	72·0 Grm.	90·6 Grm.
2017. A. ..	6·1	7·1	9·15	10·15
3137. D. 12 ..	6·85	8·6	10·8	11·9
3137. D. 1 ..	8·65	11·4	14·6	16·3

TABLE VII.—*Diamond No.* 3.

Material.	Width of Scratch in μ at Load of					
	0·93 Grm.	2·12 Grm.	4·68 Grm.	7·13 Grm.	9·36 Grm.	11·41 Grm.
Lead ..	6·1	12·2	20·0	27·3	31·2	—
Rolled Copper	—	2·94	5·6	7·36	8·4	9·65
	Width of Scratch in μ at Load of					
	11·4 Grm.	26·7 Grm.	45·3 Grm.	72·0 Grm.	—	—
Commercially pure nickel	4·6	8·0	11·2	14·3	—	—

are given in Table III, and the squares of the widths of the scratches plotted against the loads are shown in detail in Figs. 6 to 9 and together in Fig. 12. It is seen that results similar to those obtained with diamond No. 2 were given by diamond No. 3, but in this case the lines obtained intersect at a different point, Fig. 12. The scratches made with this diamond showed narrower bands at the bottoms than with diamond No. 2, and it is interesting to note that the point of intersection of the lines for the different materials is very near the origin.

Further confirmatory tests were also made with diamond No. 1, but since the edges of scratches made by this diamond were not good the widths could not be measured to the same degree of accuracy as with the other diamonds. The results of these tests with diamond No. 1 are given in Tables IV, V and VI.

The results given in Table IV were obtained by the use of the diamond in an exactly similar manner to diamond No. 2, and those in Table V in the same way, but with the test-pieces horizontal. The results given in Table VI were obtained by the use of diamond No. 1, in the reversed position on the spring holder, and so arranged that the bottom leading edge of the diamond made an angle of 13½ deg. with the horizontal test-pieces. In the results, these three conditions have been denoted by conditions B, C and A respectively. The results obtained by plotting the squares of the widths of the scratches against the loads ar shown in Figs. 13, 14 and 15. Approximate straight lines are again obtained and the point of intersection appears to be dependent on the manner in which the diamond was used.

A few tests were made on lead, rolled copper and commercially pure nickel with diamond No. 3. The results are given in Table VII, and the corresponding curves of the squares of the widths against loads are shown in Fig. 16. These curves show the usual straight line, but the agreement with the common point of intersection is not good (see Fig. 12).

Attempts were also made to obtain scratches on glass with diamonds Nos. 2 and 3, but in most cases the scratches were ragged and the material broken away by the action of the diamond. Short portions of scratches at small loads showed flow and no cracking of the material, but the true widths at these places were difficult to determine. Scratching on glass gave appreciable wear of the point of diamond No. 3.

General Consideration of Results and Suggested Scale of Scratch Hardness.—The results obtained show that with the materials used a straight line law exists between the square of the width of the scratch and the load on the diamond, and that with each diamond under constant conditions the straight lines appear to meet at the same point for all materials. Taking p and q as the co-ordinates of this point, it appears that a law exists of the form :—

$$(P - p) = k(w^2 - q),$$

where P = load on diamond,

w = width of scratch,

k = a constant for each material.

Hence

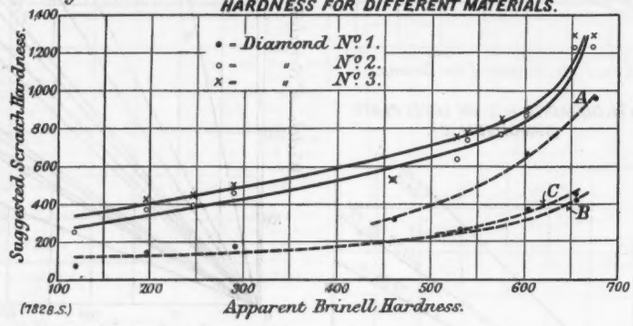
$$k = \frac{P - p}{w^2 - q}$$

k will thus be a stress, and it is suggested that the values of k for different materials may be taken as a measure of the hardness of the materials as determined by the scratch method. The calculated values of k are given in Table VIII, and the values of p and q were taken from Figs. 10, 12, 13, 14 and 15, respectively.

Scratch hardness as thus defined is shown plotted against the apparent Brinell Hardness in Fig. 17. The actual values of k appear to be dependent on the shape of the diamond and the angle with the test surface, but the type of curve is the same in all cases. The ratios of the scratch hardness to the Brinell hardness numbers are given in Table VIII, and show that a minimum value occurs at a Brinell hardness of about 450. With the exception of the value for copper, a progressive increase in the ratio occurs for both higher and lower values of the Brinell numbers. The manner in which the diamond has been used in the present tests appears to give a scratch which is of the nature of an indentation test on the materials and, therefore, agreement with the Brinell numbers might be expected. The variations in the ratios seem too uniform to be due to experimental errors, and it appears that the test does measure a property of the material slightly different from that measured by the Brinell test. The value of the ratio found for copper is interesting when considered in connection with Professor Turner's statement, that "a piece of hard-rolled copper may give a greater hardness number than one of mild steel, yet a tool made of mild steel will always cut copper and no amount of cold rolling will make copper cut steel."*

The results show that the method can be utilised to obtain a measure of the hardness of metals on the same scale over a very wide range, but at present the most useful applications would appear to be in the case of the harder materials or where only small or valuable specimens are available. For general use it seems that a standard shape of diamond would have to be adopted, since the results obtained depend on the shape of the diamond, but comparison of the results obtained with diamonds No. 2 and 3 appear to show that small variations in the angles of different diamonds do not have a large effect on the results obtained.

Fig. 17. COMPARISON OF SUGGESTED SCRATCH HARDNESS & BRINELL HARDNESS FOR DIFFERENT MATERIALS.



(7828.S.)

TABLE VIII.—SUGGESTED SCRATCH HARDNESS.

Reference Mark of Material.	Apparent Brinell Hardness No. (H.)	Suggested Scratch Hardness k in Kgm. per Sq. Mm.					k/H.	
		Diamond No. 2.	Diamond No. 3.	Diamond No. 1.			Diamond No. 2.	Diamond No. 3.
				Conditions A.	Conditions B.	Conditions C.		
2017. A. ..	674	1,230	1,290	970	—	—	1·83	1·92
1935. 1	653	1,230	1,290	—	410	450	1·89	1·98
3137. D. 12 ..	602	870	900	660	—	370	1·44	1·49
3137. D. 4 ..	576	770	850	—	—	—	1·34	1·48
3137. D. 5 ..	539	740	780	—	—	—	1·37	1·45
AEN1. G. ..	528	640	760	—	—	260	1·21	1·44
3137. D. 1 ..	459	535	535	330	—	—	1·17	1·17
T.S.	289	460	500	—	180	—	1·59	1·73
AEN1. D. ..	246	390	450	—	—	—	1·59	1·83
AEN1. C. ..	195	370	430	—	150	—	1·90	2·20
M.S.	118	265	275	—	70	—	2·24	2·33
Nickel	—	—	335	—	—	—	—	—
Copper	77	—	110	—	—	—	—	1·43
Lead	—	—	8·5	—	—	—	—	—

ELECTRIFICATION OF THE SWEDISH WEST TRUNK RAILWAY.—The Director-General of the Swedish State Railways, another high official and the chief of the electro-technical bureau of the State Railways, have returned from a visit to Switzerland undertaken in order to study the electric railways of that country. The Swedish railway officials have inspected the Swiss electric railways and held conferences with the Swiss railway authorities, who expressed their entire satisfaction with the working of the electrified railways. The final calculations for the electrification of the Swedish West Trunk Railway (Stockholm-Gothenburg) are virtually complete, the necessary grant has been voted by the Riksdag some time back; the work can be commenced in the course of a couple of months, and the entire electrification of the line can, it is expected, be finished in two years' time.

* Journal of the Iron and Steel Institute, No. 1, 1909.

CATALOGUES.

Welding Work.—Many illustrations of welding work, mostly tanks and piping, are given in a catalogue received from Messrs. R. Jenkins and Co., Limited, Rotherham who have extensive practical experience in this line.

Ball and Roller Bearings.—Two catalogues dealing with roller bearings for shafting and general use, and ball and roller bearings for motor cars, are to hand from Messrs. Hyatt, Limited, 56, Victoria-street, London, S.W.

Plate Work.—Large-scale plate work, such as steel chimneys, tanks, stills, pipes, bends, auxiliary steam plant, foundry ladles, &c. are very effectively illustrated in a catalogue received from Messrs. John Thompson (Dudley), Limited. Dudlev.

Fire-Tube Ferrules.—A ferrule of refractory material for protecting the ends of the fire tubes of boilers is described in a catalogue received from the Fuel Recovery Syndicate, Limited, 40, Westminster Palace Gardens, Victoria-street, London, S.W.

Drawing Office Supplies.—A very complete catalogue, giving prices and particulars of drawing instruments, tools, papers, inks, furniture, copying apparatus, &c., is to hand from Messrs. A. West and Partners, 36, Broadway, Westminster, London, S.W.

Varnishes, Enamels, &c.—Varnishes, japans and enamels, &c., for tin-plate printing, tarpaulins, linoleum, aircraft, &c., and suitable for various methods of application are listed in a catalogue received from Messrs. Jenson and Nicholson, Stratford, London, E.

Centrifugal Drying Machines.—A special catalogue giving particulars of representative specimens of their centrifugal machinery for extracting moisture from sugar, salt, chemicals, rags, &c., as well as for laundry work, is to hand from Messrs. Manlove Alliott and Co., Limited, Nottingham.

Lifting Tackle, &c.—Chain and rope pulley blocks, hoisting crabs, screw and hydraulic lifting and pulling jacks and some miscellaneous gear, such as rail bending crows, test pumps, engine governors, &c., are dealt with in the "Factor's" catalogue issued by Messrs. Tangyes, Limited, Birmingham.

Heat Treatment Furnaces.—The Automatic and Electric Furnaces Company, Limited, 175, Farringdon-road, London, E.C., have sent us a card pointing out the advantages of their furnaces and accompanied by a reply form to facilitate specific inquiries, or to make appointments for demonstrations.

Drills for Square and Hexagonal Holes.—A catalogue of drills, chucks, guide plates and other parts of the equipment for drilling square and hexagon holes, and suitable for use in ordinary drilling or screwing machines or turret lathes, is to hand from Messrs. E. Rollinson Neighbour and Co., 329, High Holborn, London, W.C. who are agents for these tools.

Switch Gear, &c.—Special catalogues dealing with ironclad switches and switches with fuses, cut-outs of the handguard type for pressures up to 660 volts, and gas-filled lamps, have been received from the General Electric Company, Limited, Kingsway, London, W.C. The last-mentioned catalogue gives interesting explanation of the principles of the gas-filled lamp.

Lifting Gear, &c.—Messrs. Herbert Morris, Limited, Loughborough, have sent us a catalogue giving illustrations, particulars and prices of vertical boilers; steam, electric and hand cranes of jib and overhead types; conveyors; electric trucks; winches; hoisting blocks; jacks, &c.; all of which they make in a full range of sizes and forms for general and special use.

Driving Chains.—An illustrated list of various types of driving chains and sprocket wheels with dimension tables, particulars of cutters and many illustrations of particular drives, is to hand from the Coventry Chain Company, Limited, Coventry, who also send a booklet dealing with the advantages of chain driving for textile machinery in cases where belt slip may be detrimental to the product.

Electrical Machines and Fittings.—An extensive catalogue of motors, dynamos, small fans, switch and control gear, and lighting fittings, is to hand from Messrs. Verity's, Limited, Aston, Birmingham. The motors listed range up to 100 h.p., and the series includes a large number of the smaller sizes. Many of the items listed are specially made in suitable material for ship-board use. Full dimensions, illustrations, &c., are given in all cases.

Motor Tractor.—A motor tractor made in this country and sold by the Autohorse, Limited, 16, Browns Buildings, Exchange-street-west, Liverpool, is a one-wheeled tractor which may be permanently fixed to a lorry or trailer wagon; or with two extra wheels may be automatically and detachably coupled; in the latter case the two extra wheels are lifted off the ground. Steering is on the driving wheel and the tractor is suitable for loads ranging from 1 ton to 5 tons.

Non-Magnetic Cast-Iron.—Test figures of a non-magnetic cast-iron have reached us from Messrs. Ferranti, Limited, Hollinwood, Lancashire. This material is intended mainly for use in connection with electrical machinery, both in the form of heavy parts and as a substitute for small parts now generally made in brass, gunmetal or aluminium. The magnetic permeability of the iron is about equal to that of brass, and it can be cast or machined as easily as the latter material, although the cost is much less.